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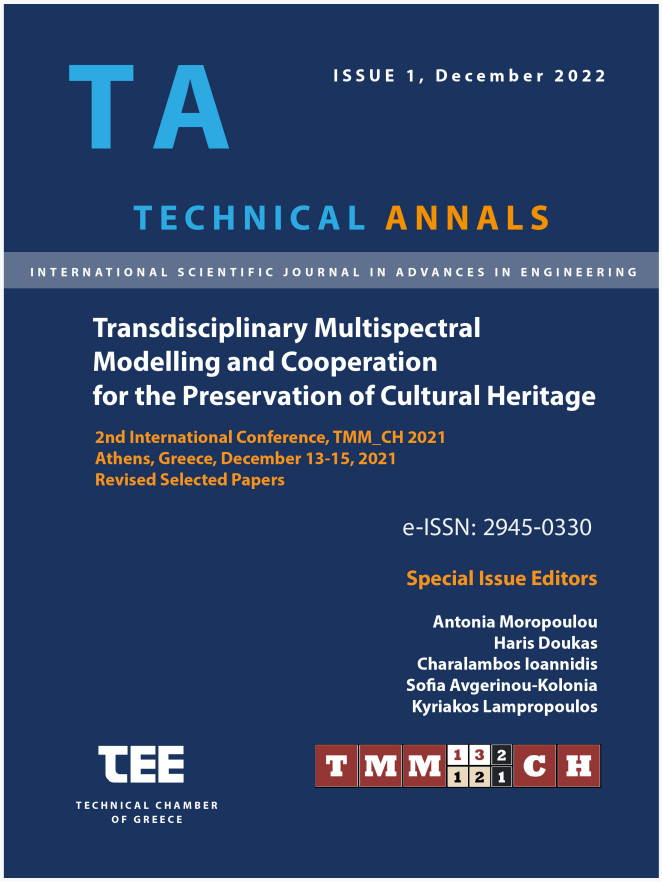

Digital heritage consolidation and innovation, three case studies between documentation and divulgation aims

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Digital heritage consolidation and innovation, three case studies between documentation and divulgation aims

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Abstract. In recent years, the need to digitize and create digital twins of the architectural and artistic heritage has been confirmed and accelerated. In this context, the DIDA-LXR (Laboratory for eXtended Reality) of the DIDALABS system, has carried out a series of research on the use of Virtual and Augmented Reality solutions to create and support activities in digital surveying, workshops for architects, and the establishment of a common knowledge basin regarding the existing architectural heritage. In this paper, several experiences are presented, and their workflows and results are shared. The selection focuses on the virtual reconstruction of the Gothic apses in the Cathedral of Fabriano; the reconstruction of the frescoes in *Santa Maria dei Bianchi* in Gubbio and the virtual reconstruction of the *Horrea Agrippiana* at the Roman Forum in Rome. Despite these four case studies being different, they all aim at creating a series of products that document the state and possible aspects of the past of significant elements of the architectural heritage. In their own way, they fix the state of knowledge and condition of these complex artefacts, preserving their memory and creating a valuable basis for any further interventions. Simultaneously, the use of today's digital tools in structures geared towards both sharing in working groups and dissemination activities makes this content available for a wide variety of processing. The technologies for the visualisation of digital works are to be considered excellent tools for the use and enhancement of Cultural Heritage.

Keywords: Digital Survey, Virtual Reality, Augmented Reality.

1 Introduction

Digital tools for survey, documentation, presentation, creating multimedia content and sharing information offers interesting possibilities with great potential in the field of cultural heritage. The creation of a digital copy from the real object is an important

step in bringing architectures, artworks, and archaeologies of any size into the present, whenever this means bringing it in taking part of contemporary procedures of manage ment, protection, and dissemination. From a single building to an entire museum to large excavation sites and a system of ruins over a large area. The tools for this transformation, thanks to their progressive dissemination over the last twenty years, are available to heritage managers, researchers and, progressively, to any visitor interested in the consistency of built heritage. From 3D laser scanners to modern photogrammetry and components built into personal devices, digital copies are being produced ever faster and in even better quality. The numerous experiences of recent years confirm the widespread use of digital innovations in the reality of individual buildings, architectural ruins, museums, and collections [4]. These changes and developments should be considered as part of the components at the base of Humanity 5.0, defined as a "society of intelligence" in which physical space and cyberspace are fully integrated [13]. The opportunity for a renewal of the logic and methodology of documenting and sharing information about architecture and art should be provided by digital innovations at all levels, starting with the tools that make it possible to move from the real to the digital with the digitisation of architectural space and to implement valuable content aimed at creating a constructive experience for the public, based on multimedia concepts and rich in qualities. The activities of the eXtended Realities laboratory, which is part of the Didalabs system at the University of Florence, aim to explore and research solutions for the use of rich content in the different situations that can occur in architecture, from design requirements to the presentation of architectural and cultural-historical themes. The strategy aims to create accurate documentation, establish a quality base, and enrich the resulting digital environment with elements of valuable interest. These solutions are designed to attract attention and convey the intrinsic values emanating from places and their history, helping scholars, students, and casual visitors to gain new information about a building's original appearance and its evolution over time. All this is done to communicate precisely, far from any desire to make the subjects spectacular and to follow a possible division of steps from the inventory to the study of the current state of the architecture to the ideas and derivations that lead to the final result. The level of accuracy of each reconstruction is always indicated, with the graphical solution used to represent the resulting model varies according to the wellconsolidated indications for the presentation and sharing of research results [1]. On the side of the tools, in all cases, the alchemy of digital surveying, mainly 3D laser scanning and photogrammetry, is used to produce correct documentation of the architecture "as is" and as a suitable basis for further studies. The 3D laser scanner units and the cameras are selected on the basis of the specific characteristics of the building, while photogrammetry is used and optimised on a case-by-case basis for interiors with frescoes and/or rich details and for objects that require a model with high accuracy. All 3D laser scanner data is processed using each unit's proprietary software, then mostly aligned, and refined in Autodesk Recap. Photogrammetry is done using Agisoft Metashape or Reality Capture, two well consolidated SfM/IM based software. The first can be considered a "classic" and reliable solution since the early days of the renewal in digital photogrammetry, while the second, developed by Capturing Reality, a company recently acquired by

Epic Games, owner of Unreal Engine (a popular software for developing virtual reality environments), offers superior speeds and interesting possible future developments. Both are used to process the collected data, and the choice depends on the specific characteristics of the available images. Both use Structure from Motion/Image Matching procedures (SfM/IM), a distance representation technique that, starting from points extrapolated from 2D images, allows the reconstruction of three-dimensional objects in the form of a textured mesh [7]. At the end of the process, the resulting polygonal mesh surface, together with its texture, provides a digital model that can be optimised for the following steps leading to the final virtual environment. The occasion of developing virtual contents with full quality and dedicating a proper time to research about virtual reconstruction and using the resulting models as a ground test about the realism of the hypothesis took place in more than one occasion across the last period, it took inspiration and reference from other researcher valuable experiences [2, 3, 10], and found the benefit of exploiting previous initial experiences from the DIDALXR laboratory [12] and then arriving to the case studies described in the following lines.

2 Case study one: Gubbio

2.1 The Church of Santa Maria dei Laici

Starting in July 2021, the complex of the crypt of Santa Maria dei Laici in Gubbio alongside the entire church were surveyed panoramically from the inside and outside photogrammetrically, with 3D laser scanning and VR. The survey formed the basis for the subsequent virtual reconstruction of the complex. The church of Santa Maria dei Laici, also known as the “Church of the Whites”, is located opposite the Basilica of San Francesco and is situated between the piazza dei Quaranta Martiri and via Piccardi. There are two entrances, both from via Piccardi and from under the loggias. There are several important works in the church, but the most important is the cycle of 24 panels painted by Felice Damiani around 1607 on the theme “Life of the Virgin” [8]. The church is built on two levels, presumably due to a series of alterations and transformations. On the first level, there is a frescoed underground chapel and on the second level, the devotional space. An opening in the floor gives access to the crypt, through which one can glimpse the level below, where part of the frescoes depicting the “Passion of Jesus” can be seen. These frescoes have always been a cause for concern, as they are in a state of disrepair, mainly due to the dampness in the place. The chapel was flooded by the Camignano torrent in 1858 and 1862. The damage was considerable, as the basement has windows overlooking the torrent [5]. In the course of the last restoration works in 1963/64, the frescoes were taken down and moved to the former refectory of the monastery of San Francesco, but some were preserved as the degree of damage was considered too great to remove them from the walls. During 1973 they have been moved to the Cathedral Museum. In the church, an opening in the floor allows to see the level below, with parts of the walls from the previous structure, enriched by some remaining frescoes. The artworks remained in place, together with some traces and parts the past building of the former appearance

of the church.

2.2 Digital survey campaign

The digital survey was considered the first fundamental step to allow the alignment and specific reading of all the remains. The photogrammetric surveys were carried out both in the church, inside the crypt and for a wooden Christ coming from the lower chapel and now repositioned in an altar, and in the Diocesan Museum, where the remaining frescoes are located. The photogrammetry for the crypt and the frescoes in the Diocesan Museum was operated using a Fujifilm Gfx50s, a 50MP digital medium format equipped with a Fujinon 32-64mm f4 lens, while a Nikon D850, a full-frame DSLR with a resolution of 47.3MP equipped with a Nikkor 16-35mm f4 lens. This second camera was used for the wall fragments emerging in the church, and for the statue of Christ. For this last specific survey, a total of 850 photos were taken and processed, the size of the statue was defined using some direct measurements taken at strategic points on the statue to determine the actual dimensions. Reality Capture was used to reconstruct the three-dimensional model of the statue, producing a polygonal surface of 267 million triangles. Additionally, a simplified version was made downsampling the model to nine million triangles with the application of the texture with two atlases of 16,000x16,000 pixels, this lighter model was then used for multimedia purposes, like its inclusion in the Sketchfab.com online archive. The 3D laser scanner survey of the whole church and of the rooms in the Diocesan Museum was carried out using the Z+F 5006h imager unit. This unit has a nominal maximum range of 80 metres and a minimum range of 0.4 metres, with a speed of max. 1.016 million points/sec. Nevertheless, this unit is not "that new" and has the disadvantage of weighing 14 kilograms, which thing requires some skill and planning to make some practical passes. Concurrently, the device is well suited for this type of use due to its excellent accuracy and high reliability.

2.3 Creation of the virtual tour

The structure of the virtual reconstruction assumes that the chapel was part of the original structure of the church, in time transformed into the present configuration and changed into a sort of crypt. The reconstruction process starts from the repositioning of the frescoes from the Diocesan Museum back into the chapel, recreating a new painted skin for the spoiled walls. Following the repositioning of the statue of Christ in its original configuration, laying, dead, on the plate inserted at the side of the main altar. The reconstructed system of the frescoes allows to have a new perception of this space, reading the relationship between the artworks and the people of that time entering this space surrounded by the histories of the Passion of Christ from the bible with an extreme description of details and the possibility of exploring them and getting notes about the main characters and events.

Fig. 1. The present state of the "Tomb of Christ" and its virtual reconstruction.

The whole reconstruction is available in the form of a virtual tour based on full panoramic images; a solution based on HTML language that allows a complete structure of the pages that remain independent from any proprietary software based on expensive subscriptions. The virtual tour is enriched by the possibility of passing continuously from the present state of the church to its virtual reconstruction with the insertion of virtual interactive models available for being inspected, like the statue of Christ and the schematic sequence of the evolution of the church.

3 Case study two: Fabriano

3.1 Digital survey campaign

This research was aimed to the reconstruction of the gothic apses of the St. Venanzio Cathedral, heavily transformed in time from a central space with radial chapels into a large central space hosting the main altar [De Marchi, 2017]. The study began with the use of a 3D laser scanner to digitally survey the apsidal area of the cathedral of St. Venanzio, followed by photogrammetric integration and final post-processing of the acquired data. Several processing steps were performed on the point clouds and the photographs taken during the survey to allow a complete interpretation of all the possible trace from the past aspect of this architecture. A first photogrammetric, 3D laser scanning and VR panoramic survey of the cathedral's apsidal complex was carried out in June 2020, then followed by a photogrammetry and panorama shooting campaign held in February 2021. The survey formed the basis for the subsequent virtual reconstruction of the complex as it presumably looked before the 15th and 16th-century alterations and putting back in evidence the frescoes by Allegretto Nuzi [9] and other painters from the XIVth century. The survey work was carried out with the Z+F 5016 3D laser scanner, the photogrammetric images with the Fujifilm GFX-50s medium format digital camera with 50 MP resolution. The panoramic images of the present state were taken using a Insta360 Pro2 camera.

After the individual scans were aligned using Autodesk Recap, the reference elements were extracted from the point cloud and used to adapt the photo coming from the first survey campaign. The post-processing began with geometric straightening of the photos in Autodesk Autocad using the Raster Design module and then pasting it into Adobe Photoshop for further steps. Thus, this method was not satisfactory as the particular morphology of some surfaces combined with the narrow working spaces re-

sulted in severe deformations in some photos that could not be properly corrected. So, a new photogrammetric session was planned in which the remains of the frescoes were entirely captured in high resolution. The photographs were processed in Reality Capture. In this way, high-resolution planar view of the frescoes was produced, and in a solution well compatible with the previous 3D laser scanning dataset. The photoplanes were mostly created with Reality Capture and, in some cases, with Agisoft Metashape. They were later post-processed using Autodesk Autocad Raster Design to refine the final geometry of these textures. The different photoplanes were connected to key points at their original position on the point cloud in Autodesk Autocad after proper colour and post-processing adjustments in Adobe Photoshop.

Each completed component was then shared with other members of the research team to reconstruct the missing parts of the frescoes and provide a basis for any ideas about the original architectural aspect of the building. The 3D model of the former St. Venanzio cathedral progressively took shape, constantly adjusting the structure of the frescoes, the traces left by the interventions in the masonry and some elements that can testify to the former configuration. The final 3D model, showing the articulated form based on a sequence of 6 chapels opening onto the central space of the apses, was later textured with the reconstructed frescoes, and used as the basis for creating panoramic images for the virtual tour.

3.2 Creation of the virtual tour

For the presentation of the reconstruction of the frescoes and the cathedral, the total online option for visualising and using the preserved research material was preferred among the various virtual options available. In order to put all the content in context, a virtual tour of the present cathedral was created using an Insta360 Pro2 camera providing panoramic images in 8K resolution. Everything was built around a virtual tour with a very intuitive and simple initial structure with a simple menu with basic instructions. Included in this virtual tour are panoramic views that offer the possibility to access various detailed information about the different structural and decorative elements; most of this additional information allows access to the virtual reconstruction of the cathedral "as it was". All the construction of the user interface and multimedia content was done using Garden Gnome Pano2Vr 6.1, and the final virtual tour was then exported in HTML format. In the end, the virtual tour was enriched with hotspots and clickable areas that allow access to enlargements, information panels, graphic diagrams, short videos, and other content that complement and enhance the quality of the experience. Thanks to automatic gyroscope detection, the orientation of the viewing angle can be changed in real time via smartphones and tablets. An additional button has also been added to switch to stereo 3D mode for VR headsets such as Oculus Rift S/Quest and HTC Vive Pro (or even simple smartphone-based adapters).

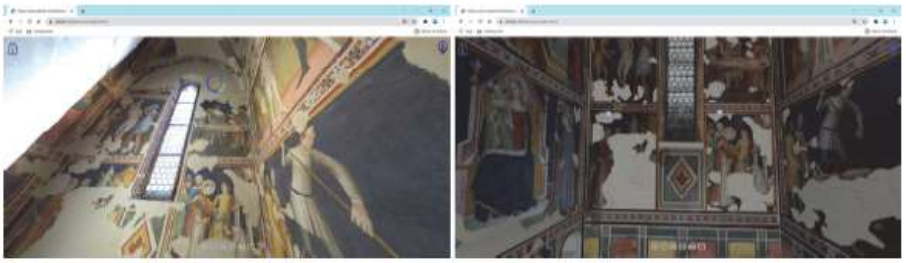

Fig. 2. The chapel of San Lorenzo by Allegretto Nuzi: present state and virtual reconstruction.

The virtual tour was presented on a dedicated website (available at www.didalxr.it/fabriano) that can be adapted and used on smartphones/tablets, notebooks, or other devices. The same virtual environment has also been optimised for use on a large touchscreen in the Fabriano Art Gallery, just in front of the cathedral of St. Venanzio. The touchscreen in the art gallery is an 86-inch Philips screen (Signage Solutions line, model 86BDL3012T) connected to PC and providing direct access to the online version of the virtual tour. The positioning of the screen has been optimised to make the touch function as easy and practical as possible for each user. The main menus have been positioned in the lower part of the screen and the height of the screen has been adjusted so that the centre of the screen is about 1.5 metres above the ground so that the virtual tour can be operated efficiently even by children or wheelchair users thanks to the size of the screen and the gesture functions.

4 Case study three: Horrea Agrippiana

4.1 Historical background

This research is based on virtual reconstruction and the possibilities it offers to all scholars in the field of archaeology and architecture. In recent years, technological developments, and the curiosity to investigate how certain sites or buildings might have looked in the past have led to an awareness of the importance of survey technologies, digital investigations and tools such as XR (augmented realities) for implementing the collected data.

A *Horreum* was a public storehouse where different types of supplies were stored during the Roman era, primarily of course those containing food and grain. At the end of the imperial era there were about 300 of them, but today the *Horrea Agrippiana* are the only ones in Rome whose remains can still be visited [11].

According to most researchers, the *Horrea Agrippiana* date from the time of *Marcus Vipsanius Agrippa* and are dated to between 20 and 10 BC. They are located to the northwest of the Roman Forum, between the church of Santa Maria Antiqua, the church of *San Teodoro* and the Domitian group, and bordered by the *Clivus Victoriae* and the *Vicus Tuscus*, the street that took its name from the Etruscan colony that came to Rome with Tarquinio the Superior.

The building was arranged around a large courtyard and surrounded by shops on the street. It presents itself as a huge two-storey building consisting of large square rooms made of tufa blocks, partly opening on to the courtyard with a porch and were later occupied by other smaller rooms made of bricks. This area was one of the most feverish for the economy.

4.2 Digital Survey

To reconstruct and virtualise the ruins, two types of surveys were carried out to obtain the material necessary to achieve this goal: a digital survey for photogrammetry and VR panoramic survey. A third survey was carried out onsite with a 3D laser scanner, an Imager 5016 Z+F. The photogrammetric survey was carried out in three distinct steps, comprising data acquisition, elaboration, and recovery, to get a comprehensive and detailed documentation based on the SfM/IM technique. The instrumentation used consists of a Nikon D850 camera with a Nikkor 16-35 mm F4 lens; the sensor, thanks to the intense summer light, was set at a low sensitivity, whit an ISO value of 64, reducing to the minimum any possible presence of noise. The full series of shot was finished counting a total of 1900 photographs.

For the VR panoramic survey, the aforementioned Insta360 Pro2 was used to capture spherical 360 HDR videos and images at 8k resolution. The surveyed area is very large and therefore the stations were planned to achieve the most complete result possible and avoid repeating data. After shooting, the data was imported into the special software Insta360Stitcher, which offers the possibility of setting useful parameters to enhance the quality of the stitching and image correction, creating high quality panoramic images rich of details and free from alignment defects.

4.3 Digital reconstruction and virtual environment

To achieve a high-quality result, the operations carried out in the reconstruction phase must be accurate and based on solid archaeological and historical research. The support by the archaeologists taking part to the research were fundamental in creating a specific reconstruction as well as their indications about other similar building from the Roman age, a fundamental match to allow a digital reconstruction.

To obtain a digital reconstruction of the anastyloses, the archaeological analyses formerly carried out was transferred into a 3D model. The model was created using Maxon Cinema4D software and later inserted into the context of the *Horrea Agrippiana* created by Reality Capture. Epic Megagames Unreal Engine 4 (UE4) was then used to create virtual content that can be used to design the environment in which the digital model can be visited and explored.

4.4 Virtual tours

The ultimate step of this research was to develop three different types of tours, depending on the distinct possibilities we wanted to achieve. The first tour is an interactive 360° tour that was created using CGI technology with UE4. The 360° images are then edited, exported, and imported into the Gnome Garden Pano2VR software to make the tour accessible to everyone, with interaction and historical knowledge.

(https://www.didalxr.it/2021FMHorrea).

Fig. 3. The treatment of the panoramic image in the Insta360stitcher and a view from the virtual tour of the Horrea Agrippiana.

In the second type of tour, which always starts from the same environment created in UE4, an immersive virtual tour has been created that gives the user a fully experiential interaction with the virtual environment they are immersed in. Access is via the headset VR. Finally, a 360° tour with panoramic images of the insta360 pro2 was created, offering a picture of the current state of the archaeological site, in contrast to the previous tours that rather try to tell the story of the site in the past. The possibility of using these tools to verify the effectiveness of the results of research and studies in archaeological and architectural philology should be a starting point for a new approach to the study of the existing architectural heritage.

Conclusions

The experiences conducted in the past two years by the DIDALXR laboratory confirm how the digital reconstruction and be a way for learning and better understanding the built heritage values, with the production of valuable contents that can be shared with other users and visitors to allow them to make a step forward in the comprehension of a distant, but extremely fascinating past. Most of all, these experiences demonstrate that spectacularizing the virtual reconstruction is not the most preferable way to communicate Cultural Heritage values. The honest sharing of the reconstruction process and the right balance between each contribution in the research teams allow to build positive experiences that add qualities to the rich, but often misinterpreted, patrimony from archaeological and very old sites. The virtual reconstruction when presented in immersive solutions is capable of conquering a robust grip in the interest of visitors, but most of all it is a significant test ground for the quality of the contents and the reliability of the final result. The direct exploration from the virtual environment leaves no space to weakness or unsolved parts, it requires more completion than a single static image or a video sequence. The three experiences presented here are part of a patrimony that in the past suffered from abandon and neglection, before been recognized for their real value as important witness of a distant and fascinating past. The digital solutions allow to bring these architectures closer to a public interested in technologies and capable to appreciate the integration of digital solutions and art-

works. A challenge that passes by creating proper contents, enhancing the inner value of a patrimony characterized by an incredible beauty.

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References

1. Beacham, R., Niccolucci, F., Denard, H.: An Introduction to the London Charter. In: The Evolution of ICTechnology in Cultural Heritage, Papers from the Joint Event CIPA/VAST/EG/EuroMed Event. (2006).
2. Canzoneri, A., Pavoni, G., Callieri, M., Dellepiane, M., Pingi, P., De Giorgi, M., Scopigno, R.: A Virtual Experience Across the Buried History. In: Augmented Reality Virtual Reality, and Computer Graphics, Proceedings of the Third International Conference, AVR 2016 Lecce, Italy, June 15–18, 2016, Part II, pp.158-171. Zurigo, Swit- zerland (2016).
3. Chittaro, L., Ieronutti, L., Ranon, R., Siotto, E., Visintini, D.: A High- Level Tool for Curators of 3D Virtual Visits and its application to a Virtual Exhibition of Renaissance Frescoes, Geneve, Switzerland (2010).
4. Collotti, F.V., Verdiani, G., Brodini, A. (eds.): Proceedings of the first ArCo Conference, Didapress, pp.123-262 (2021).
5. Costantini P.: Ipotesi sulla topografia della antica Gubbio, Olschki, Florence, Italy (1976).
6. De Marchi, A., and Biondi, L.: Elogio del Trecento fabrianese. Materiali per Allegretto Nuzi e dintorni. Mandragora, Florence, Italy (2017).

7. Guidi, G., and Gonizzi, S.: Image preprocessing for optimizing automated photogrammetry performances. In ISPRS Ann. Photogrammetry and Remote Sensing. Spatial Inf. Sci., 145-152. Volume II-5. (2014).
8. Luongo, A.: Gubbio Nel Trecento, Collana: Italia comunale e signorile, 9, Viella Li- breria editrice, Rome, Italy (2016).
9. Marabotti, A.: Allegretto Nuzi. Leo S. Olschki, Firenze, Italy (1951).
10. Papagiannakis, G., Schertenleib, S., O'Kennedy B., Arevalo-Poizat M., Magnenat- Thalmann N., Stoddart, Thalmann A. D.: Mixing virtual and real scenes in the site of ancient Pompeii, New Jersey, USA (2005).
11. Pronti, A., Astolfi, F., Guidobaldi, F.: Horrea Agrippina, Archeologia Classica. L'Erma di Bretschneider, Rome, Italy (1978).
12. Ricci, Y., Verdiani, G., Pasquali, P.: A petrified petrifying eyesight: a story for the Medusa's heads from Istanbul, Turkey. In proceeding of Cultural Heritage and New Technology 23 Conference, Vienna, Austria (2018).
13. Salgues, B.: Society 5.0 Industry of the Future, Technologies, Methods and Tools, ISTE, Wiley & Sons, Hoboken, Usa (2018).