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Experiences of industrial archaeology in Italy: from survey to museum use

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***Abstract* – This paper concerns the results related to thr construction of a section of the "Museum of the Brickwork of Marsciano" (Perugia, Italy) with installations for museum communication. The digital approach to information is able to collect and simultaneously make available to its users a huge number of documentary resources, encouraging interdisciplinary approaches, promoting cross paths and unexpected connections. All these issues are referred with the use of digital technologies based on 3D approach. The use of hybrid photo restitution, digital photogrammetry, serious games and immersive narratives, makes it possible to emphasize the cognitive process through the dramatization, persuasiveness and emotional approach. Within these museum have been developed several applications, intended as an "enabling platform", which allows visitors to learn the technical innovations in the production of bricks. The whole of these different technologies, should guarantee a response to the different requests of the public, allowing -to a certain extent- the overcoming of the digital divide and the cultural divide.**

I. RESEARCH CONTEXT

The availability of immersive technologies makes it possible to open to the public, at least virtually, those cultural contexts which, for different reasons, have problems of accessibility, visibility and knowledge. Their three-dimensional restitution starts many mechanisms of enhancement and use, but above all allows an integrated knowledge of the cultural heritage. The case studies presented here have two main purposes: the first is to obtain a faithful survey of the current state, suitable for all conservation purposes, the second is instead oriented to their use, above all for the benefit of the disabled.

In 2017 the IBAM-CNR, in collaboration and synergy with the municipal administration of Marsciano (Perugia, Itlay) and with all the others parties involved in the project "Dynamic Museum of Brick and Terracotta", provided multimedia products concerning the development of interactive applications for museum communication. These were aimed at promoting:

- historical knowledge on brick production in Umbria and in the Marsciano territory between pre-industrial and industrial age;

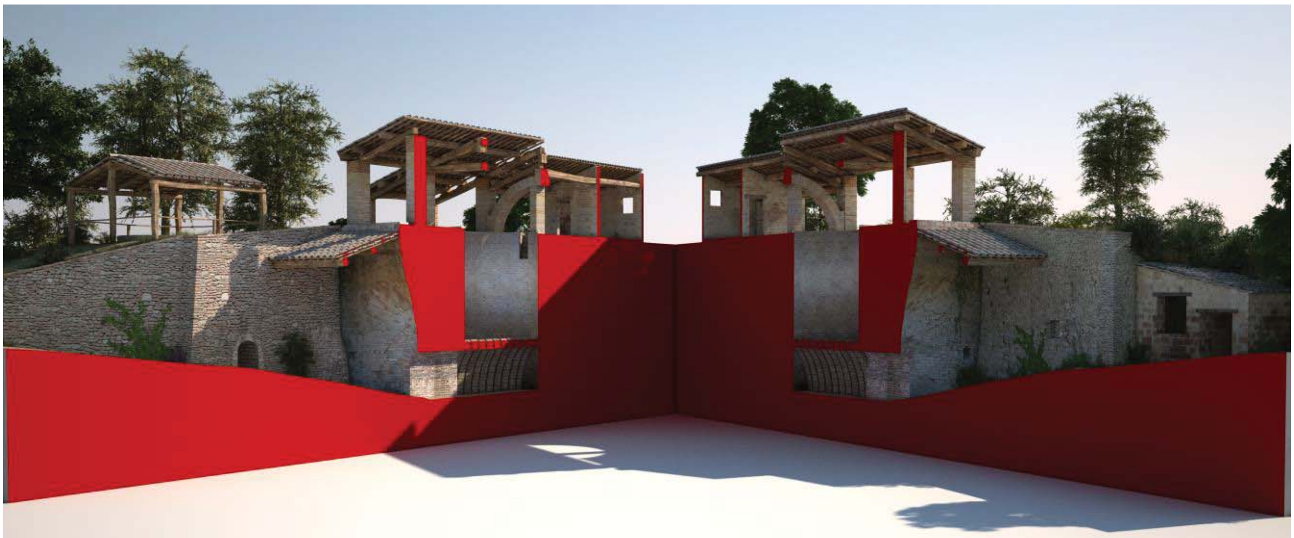

Fig. 1: Several point of view and several movie representation aid the visitor to understand the production process and this simply and efficient building. Cross-section of the pre-industrial furnace of Compignano.

- technical innovation and industrialization in the production of bricks;
- the analysis of an industrial process and of the brick production, both in the old furnaces and in Marsciano factory.

Within this project, an interactive application has been created that allows users to learn about the archaeological and industrial heritage of the territory, also through reconstructions and animations of production processes.

II. COMMUNICATION METHODS

The new forms of museum communication, based on dynamic narration and multimodal information, have greatly changed the expository logics for museums and the ways in which cultural contents are used by the public. At the same time, the impulse of new technologies has strongly imposed new hybrid forms of communication (Gabellone F.,2013). From recent studies it is clear that all the exhibitions that have characterized their cultural offer through digital technologies and the active participation of the public, have obtained the greatest successes in terms of turnout and, probably, a greater understanding of the cultural information communicated. Multimedia communications, the prevalence of iconic information on the written word, and the freedom of use allowed by new technologies, therefore radically change the perceptive and cognitive processes: from analytical, structured, sequential and referential, they become generic, global, simultaneous and holistic (Muscogiuri M., 2005). The integration of communication criteria based on the image and on the use of immersive and participatory technologies, in our project, is based on some assumptions. Before the introduction of the written word, seeing was not a structured decoding of graphic signs, but only a perception of images, experienced in a more sensorial, emotional and less detached way . In the "image society", with the pervasiveness of television and multimedia tools, the cognitive process returns to be based on the image. However, this process has led to the consolidation of the so-called “cultural divide”, the cultural gap that separates those who are familiar with books, newspapers, magazines and other information and dissemination tools, and those who have television as the only reference, from a communicative point of view (Michael, D. & Chen, S., 2006). Recently they were the cultural tools due to the social class, the employment, or simply personal predisposition to define this nuanced line of demarcation. From a few years has emerged the further line of demarcation of the “digital divide” (Corti, K., 2006), the digital gap between those who have the possibility and the skills to use the new information technologies and those who are cut off from it. Determining factors, in this sense, are above all the age and the employment, which often encourage the use of IT tools and Internet. Vice versa, the familiarity with the computer instrumentation is a necessary condition but not sufficient to ensure the acquisition of culture and information.

The construction of a section of the “Museum of the Brickwork of Marsciano” (Perugia) with installations for museum communication, activates a dynamic mode of learning and cultural enjoyment, and increases the sense of infrastructure of knowledge to which a place of culture must respond today. The digital approach to information is able to collect and simultaneously make available to its users a huge number of documentary resources, encouraging interdisciplinary approaches, promoting cross paths and unexpected connections based on cultural serendipity (Muscogiuri M., 2005).

III. THE PRE-INDUSTRIAL FURNACE

The results of the work mainly concern the forms of digital representation of the furnaces described above, in the broader goal of understanding production processes. The furnace of Compignano is known as a pinion furnace. A truncated cone-shaped brick construction, about 7 meters high, with a diameter of 3-4 meters, consisting of a lower part, covered with vault, in which the fire is prepared, and an upper part containing the artifacts to be cooked. The heat spreads upwards, through cracks specially created in the brick partition floor. From here the heat reaches the cooking chamber above, previously loaded and closed with a brick wall, in which cracks are left to allow the escape of gases and fumes. The degree of cooking was checked by observing the colour of the bricks. The furnace of Compignano represents a precious testimony of the ancient brick art, an artisan activity that has characterized the economy of the Marsciano territory since ancient times. It is difficult to date the period of first plant, but in a brick from the upper part of the furnace it is engraved “1775”, maybe the year of construction. At first the kiln probably belongs to the Ottaviani family, in the nineteenth century one of the most well-to-do families of Compignano, in the twenties of the twentieth century it was taken over by Ettore Corneli. The production process started between autumn and winter with the preparation of clay. Once dug with hoes and spades, it was transported to the "piazza" in front of the canopy, piled up into two distinct mounds one meter high, and left exposed to atmospheric conditions to make it more malleable. The production of tiles derived from the "gagliarda" (strong) clay, that is to say strong, dug at a depth of more than one meter (Riccieri A., 1814). From the less strong clay, dug at about one meter of depth, were produced little tiles. The latter were thicker and larger than the tiles, so their thickness and mass balanced the poor quality of the clay used. This type of furnace allowed to produce about 40.000 pieces of clay per season, and the whole production depended on the expertise of the kilnman, who controlled the whole cooking process. Of course, the annual production

Fig. 2: 3D survey and virtual reconstruction of the pre-industrial furnace of Compignano.

rhythmized an economy that proceeded according to seasonal rhythms, far from an industrial production logic. Bricks production considerably grows after the introduction of the Hoffmann furnace (named as its inventor Friederich Hoffmann, Groningen, Holland, 1818 - Berlin, 1900). This furnace makes it possible to produce bricks continuously, without seasonal interruptions. It consists of at least 12 chambers (or cells), arranged to form two parallel bodies of contiguous environments connected by two semi circular rings (Ferrini R., 1876). Each room communicates with the next one through tunnels equipped with valves, and with the outside through doors closed by provisional walls of raw bricks and with the chimney that disperses the combustion exhaust gases, used to produce the heat needed to cook bricks. The Hoffmann system therefore guarantees continuity of the production cycle and considerable energy savings. The brick are fired by the continuous movement of heat, which moves from one chamber to another, subjecting the cooking chambers to different temperatures. The principle of the Hoffmann oven is therefore based on the continuous motion of combustion and on the differential temperatures of the adjoining rooms, which are cooled or heated progressively by the air flows, that start from the living flame. The functionality of this system, however, was soon questioned, due to the difficult handling of bricks, which had to be manually loaded and unloaded by the workers, who were in extremely difficult and uncomfortable working conditions, especially due to the continuous changes in temperature they were subjected. The evolution of the production process therefore reaches its most stable evolution, up to the present day, with the introduction of the tunnel oven. In this cooking system the bricks move in a straight line, inside a real tunnel, and the cooking happens with the progressive heating of the various sectors. The bricks go inside the tunnel at relatively low temperature, during the journey in the oven the temperature progressively rises up to the centre, where it reaches the maximum temperature, then gradually decreases towards the exit. In this way cooking takes place with a high-level control, and the whole "in line" process can be easily industrialized and mechanized. The subsequent technical improvements, since its introduction, have mainly concerned the preparation of the clay, its granulometric control and the drying phase, but the great innovation regards the simple and direct mode of this system, extremely efficient, compared to those previously described. From a communicative point of view, we therefore wanted to tell, in short, all this technological evolution in addition to animated graphics. The reconstruction has assumed two distinct attitudes: for the furnace of Compignano we have tried to "restore" the place of production as it appears today, highlighting its value as a historical testimony. We have used a self-explanatory approach, with few captions and comments, precisely because of the great communicative power of synthetic images.

IV. SURVEY AND MODELS OPTIMIZATIONS

An important contribution to this project was given by the possibility of restoring the evolution of cooking techniques in hyper-realistic way. In particular, the Compignano furnace, still well preserved, has been completely rebuilt in 3D through the use of mixed techniques. A first acquisition of the structures was performed with digital photogrammetry techniques, now well known and widespread. As often happens, however, many architectural elements cannot be correctly acquired with this technique due to various problems, including: impossibility of illumination of narrow environments; inability to reach inaccessible parts; impossibility of overflight with APR, etc. Leaving aside the wide range of possible barriers to well survey entire objects, the solution to these problems is given by manual modeling of the hidden elements. In the case of the Compignano furnace, these elements have been identified by the use of control points. These are easily recognizable, detected with photogrammetry, and referenced in the overall model. Subsequently the missing parts were modeled manually, with direct survey or indirect laser measurements. Some measurements have been obtained by deduction or simply by subtracting known measurements. However, the complete restitution of the Compignano production complex, required a particular effort. The 3D models obtained directly from photogrammetry gave unsatisfactory results. Many elements were excessively "polygonized" and others weren't satisfied, with incorrect morphological information. These anomalies are very often found in surveys of this type, especially with reference to difficulty or impossibility to reach some areas. Furthermore, for the purposes of maximum understanding and storage of the obtained data, the 3D model of the furnace was used to obtain an interactive file, for which an optimization process is required. Generally, the optimization of three-dimensional models for flexible reuse in real-time 3D environments requires an export in generic interchange formats and a reprocessing of the textures with shading removal. To this end, an “object baking” process has been done, widely used in CG, above all to eliminate problems of portability of the models between different software, but also to simplify the computing in the final rendering.

Fig. 3: 3D reconstruction aid the museum visitors to understand productive processes.

With this technique, it is possible to transform a complex object with many textures, into an equivalent object in which only one texture is applied. This texture has been generates in UVW projection, with shadows, ambient occlusion and, above all, with all pre-calculated radiosity. This technique is widely used in video games and especially in real time applications, since it is always preferable to manage scene with shadows and pre-calculated radiosity (Gabellone F. et alii, 2017).

The application of this procedure has been very useful to solve blending problems between contiguous textures, but also to obtain a unique texture for a group of objects within software for interactive real time exploration. Typically, bake texture is an automated operation in most 3D software, but it is one of the most useful operations for texturing of complex objects, especially when many textures are used on a single object, or different textures are applied only on certain polygons. For the monuments under study, it was necessary to optimize the unwrapping process, the way in which the individual 'pieces' of texture are sorted in a planar frame-picture. The same process that is done when it is necessary to represent the earth globe on the plane. Since at the end of the baking process the resulting UVW texture is square in shape, it is possible to have, on the same 3D model, a single texture, but with different resolution. This is because a square texture can be scaled very easily, keeping the mapping correct. As a consequence of this, a simplified management of the LOD (Level Of Detail) is obtained, to the benefit of progressive loading on mobile devices. A further element of primary importance for the reuse of 3D models in different authoring environments, each characterized by different lighting setup and mood, is given by the lighting of the object itself at the time of survey. As known, photogrammetry or other texture mapping technique based on real photos, such as that used for the furnace, generates non-BRDF shader, that is, not characterized by physically accurate description of the reflections, refractions, roughness, etc. (Brusaporci S., 2015). The texture generated with photogrammetry shows exactly these characteristics, but as results of the existing lighting. The process shows only one light condition. Consequently, the use of these models in different light conditions from the original ones is not recommended. The positioning of a light in the 3D scene with color temperature and orientation different from those documented in situ at the time of shooting, generates an aesthetic "contradiction", very problematic in the video production phase. A first method for removing these cast shadows is given by the use of an "albedo" texture. This has similarities to the diffuse map where lighting information has been removed. It is difficult to get a photo without lighting information and, in general, controlled laboratory lighting is required to do this. However it is possible to generate an albedo texture with some specific software, for example an Unity plug-in or Adobe Subsatance 3D. This software will generate albedo, roughness, environmental occlusion and normal map from normal photos. A similar result is obtained within the photogrammetry SW, such as Agisoft Photoscan, through the "remove lighting" function. The method, in addition to eliminating the strong lighting contrasts, allows to illuminate 3D objects with sources that have a different direction from that present in the real scene. A second critical element, on the other hand, refers to the color correction. In this work we have used a simple solution. We have made photographic shots with natural light, because exposure to natural light often produces only very small color cast. The use of this reference base, without major chromatic alterations, was subsequently used as a reference for the "color matching" function in Adobe Photoshop. The last phase of geometry optimization is the reconstruction of "topology", a process known as re-topology. This operation consists in the reconstruction the mesh shape of an object both with automatic techniques and with manual tracing, in order to obtain a simplified shape, draw with curves and surfaces defined in mathematical way (generally NURBS, but also simple polygons). There are several commercial and open source solutions (see: https://github.com/wjakob/instant-meshes https://developer.blender.org/T67997 https://www.3dsystems.com/software/geomagic-wrap etc.) which allow to simplify and optimize the geometries produced by laser scanning and photogrammetry. In any case, the re-topology process allows to obtain models with continuous surfaces, without discontinuity and evident anomalies. The presence of poorly characterized or reflective parts of the real object, or parts not adequately covered by photographic shots, produces measurement errors, with the presence of holes in the geometry or high noise, with “orange peel effects” and swellings, foreign to the real form of the object.

The most interesting aspect of this technique is given by the ability to obtain, starting from these 3D models obtained from digital photogrammetry, new models in which the distribution of the polygons is continuous and regular, without redundant information (Gabellone F., Chiffi M., 2015).

If used with careful control of the results, this method can repair little measurement errors, getting some parts of the model back to an acceptable shape for this type of use; especially in video products for museums, where the expected result is not a “perfect” metrical survey, with sub-millimetric precision, but the communication process obtainable with these 3D models.

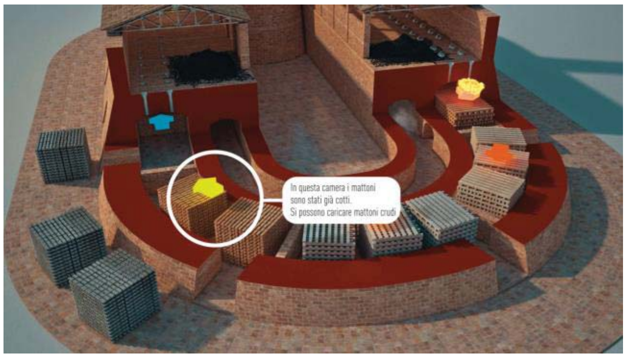

Fig. 4a-4c: From top to bottom: the interactive App with the informative 3D model. The Hoffmann furnace and his most recent evolution: the Tunnel Furnace .

V. CONCLUSIONS

The museum contents developed for Marsciano, contains numerous unpublished media and reconstructions, aimed at helping a reading according to the new paradigms of museum communication and within the methods of virtual archaeology. As it is known, many of the techniques used today for digital representation and communication through 3D models of currently not visible artifacts refer, from the methodological point of view, to the guidelines of the Charter of London and the Principles of Seville, ratified by ICOMOS. The transmission of complex contents on the architectures of the past is made more effective by the contribution given by 3D modelling and digital representation, managed and organized within interactive applications and passive animations. For this work we have mainly used the hybrid photo restitution, with digital photogrammetry and integrations of elements detected on site with direct and indirect measurements. The main purpose is to show the evolution of the production processes of the brick, starting from the pre-industrial furnace of Compignano (municipality of Marsciano, Perugia), abandoned in favour of a continuous production in Hoffmann type furnaces, ending with a more effective industrial production introduced with the Tunnel oven.

With regard to the communication of industrial production processes, we have highlighted that the set of communication methodologies, suitably integrated in a logic of "multimodality", i.e. diversification of the content offer, allow a better understanding of the production dynamics. The use of explorable 3D models, section drawings, narratives and interactive applications, improve the understanding of production contexts and especially production methods. However, it is clear that all this content must be presented in a form that facilitates usability and portability (Adams, E. 2010). Therefore, in addition to the consequences in the educational field, we have also presented techniques for optimizing 3D models for use in game development environments. Very often, methodological errors are traceable in the optimization of scenes, especially in those aspects related to the texture and polygon distribution. For this, in a primary way, we suggest an “albedo treatment” and quad-mesh optimization, with re-topology process.

The methods and techniques here exposed, have been presented with reference to the tangible results, in which what has been highlighted is the need to combine the technical aspects (optimization of 3D models) according with communication methods of and archeo-industrial research.

VI. ACKNOWLEDGEMENTS

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