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VECTORIALIZATION PRACTICES OF THE IMAGES DRAWING OF THE FLOOR MOSAICS OF THE BASILICA OF NATIVITY IN BETHLEHEM

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Abstract

The research deals with the different image vectorialization techniques for the development of reliable drawings on mosaic systems. Following the restoration of the floor mosaics of the Basilica of the Nativity in Bethlehem, surveys were conducted with digital technologies that produced a 3D database on considerable mosaic surfaces. The problem of the graphic representation, linked to the drawing of these systems, concerns both the optimization of the methodological processes in advantage of a more performing drawing activity, and the definition of the appropriate languages to satisfy requirements related to the documentation and the work restoration. Technical drawers have worked alongside restorers to produce technical drawings and a model to interact with the mosaic system, developing an informative model that can facilitate construction activities and, at the same time, enhance the entire artwork.

Keywords

Mosaics Survey, Digital Documentation, Vectorial Drawing, Interactive 3D model, Church of Nativity

1. *Introduction*

With the aim of structuring a methodology for the digital documentation and management of mosaic assets, this research deals with the issue of automation in the graphic restitution processes experimented on the case study of floor mosaics of the Basilica of the Nativity in Bethlehem.[1]

The project, conducted by the DAda-LAB laboratory of the University of Pavia, is regulated by an agreement with Piacenti S.p.A., the company charged of the monumental complex restoration activities. The objective is the definition of reliable drawings able to reproduce the individual tiles of the mosaic system on a 4:1 scale to support analysis, critical interpretations and thematic drawings useful for the restoration process.

The survey campaigns, conducted in December 2018 and August 2019, have interested the use of several digital instruments to verify the quality of the different data acquisition methods, compared in an integrated survey system[2] (Bertocci, 2006).

Following the two survey campaigns, in order to develop a rapid and reliable digital reconstruction of the decorative apparatus, ortho-images vectorialization processes of the mosaic system have been performed, obtaining reliable drawings and graphic representations for the computation of the mosaic tiles. At the same time, the research activities concerned the creation of a reliable 3D model of the mosaic system and of the adjoining architectural apparatus in order to allow the operator to virtually interact with the individual tiles and to understand the spatial qualities in relation to the context (Adami, Fassi, Fregonese & Piana, 2018).

These procedures, which have generated a functional documentary corpus to the graphic database of the important ornamental apparatus, intends to qualify the operational protocols for the structuring of a survey methodology. Moreover, in graphic restitution practices, the updating of language in the digital environment has involved a reflection on signs, symbols and different levels of headwords functional organization.

[1] The paragraphs 1; 2; 3; 6; are due to Sandro Parrinello. The paragraphs 4; 5, are due to Silvia La Placa.

[2] The digital survey activities, conducted by the Dada-LAB team of researchers Picchio, De Marco and Doria, saw the use of Laser Scanner technology (FARO FOCUS S 150 of FARO) and digital photographic instrumentation (Canon EOS 77D with fixed focal length 18 mm and SONY alpha 6000 with 24mm fixed focal length).

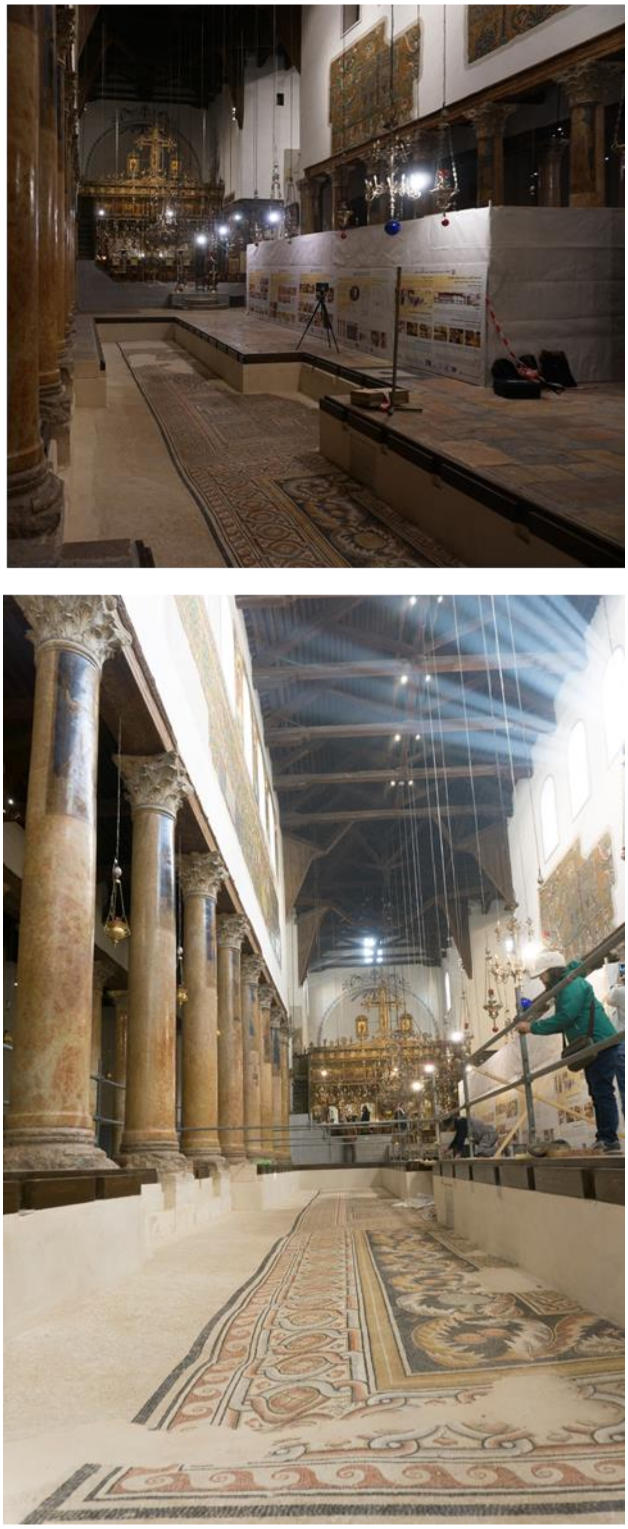

Fig. 1: The floor mosaics in relation to the Basilica of the Nativity main nave

The new design meets the growing documentary and management requirements, for conservation and, generally, for the enhancement of the heritage (Fig. 1).

2. The digital representation of mosaic systems

The documentation of mosaic works generally involves the use of digitization technologies combined with non-invasive diagnostic analysis. This integration had required drawings and graphic representations to define the areas subject to different pathologies with relative precision, to combine the metric information with other qualitative data useful for the definition of some aspects, such as color necessary to represent the decoration and the ornament in the mosaic layout.

Measurement practices thus follow the evolution of the reading methodologies for the image complexity in terms of reliability of the data acquired, conservation and restoration of surfaces (Cantisani, Garzonio & Tucci, 2006) (Monti & Maino, 2012).

The drawing becomes the container of construction and restoration site, where different activities are both marked of cleaning and pictorial reinstatement of the ornamental apparatus. For this operation, which has undergone several critical orientations over the last few decades[3] (Fiori & Vandini, 2002), the survey outputs become the fundamental tool thanks to which the restorer can perform his own functional interpretations to understand the integrity of the work. Moreover, architectural contexts, in which such decorative systems are located, are often characterized by numerous criticalities that influence the understanding and general state of conservation of the mosaic. The ancient mosaic, when it is located in its original architecture, is often subject to an irregular background linked to the failures that occurred over time (Tucci, Bonora, Crocetto, Nobile, & Al Turk, 2010). For these reasons, the analysis cannot ignore, as is obvious for any cultural asset, an examination of the relations that connect the mosaic to the context (Brumana, Fregonese, Monti, Monti, Monti & Vio, 2007) (Adami & Fregonese, 2018). At the same time, those relations characterize the components that determine its image, thus defining a hierarchical structure of relations to which the document process must be able to respond[4] (Norberg-Schulz, 1992; Parrinello 2013).

[3] About the cultural addresses that have guided restoration practices and in particular the different opinions on the treatment of gaps and pictorial reintegration.

[4] The environmental levels, as described by C. Norberg-Schulz, qualify a hierarchy of sets for which it is possible to define relational domains. These characterize a structure that

The systematic knowledge of the artwork starts from an analysis process that defines the documentation and survey project. The morphological knowledge requires the application of digital technologies to be able to successfully

Fig. 2: Details of the floor mosaic

configure different reading scales. These are, in particular, a detail scale (Fig. 2) in which it is possible to understand the tiles geometries and materials, and a larger scale, which contextualizes the mosaics within the architecture that houses them and describes the elements represented (Manferdini, 2010).

In the design of the mosaic the high number of tiles involves a very onerous process, in terms of time and of reviewing the contours of each piece. The attempt to automate this procedure is considered one of necessary objectives to ensure that this design and documentation practice is part of the usual process on mosaic apparatus studies. The automatic vectorialization of the images aims at reproducing the geometry and the drawing of the tiles, in order to obtain a 2D drawing from which it could be possible to carry out a computation for the restoration and a 3D reconstruction for a more effective understanding of the work in relation to the surroundings.

3. *The floor mosaics of the Basilica of the Nativity*

The first Nativity factory, dating back to the time of Constantine, had a floor decorated with a mosaic carpet that in later centuries was covered, raising the floor of the Basilica. The decorative apparatus was discovered in 1934 by the Englishman William Harvey, during an excavation campaign conducted following the restoration of the complex. It was then covered after its decorative perimeter was accurately documented with photographs and drawings (Madden, 2012).

In recent years, during the restorations conducted on the roofs and on the wall facings[5] (Bertocci & Parrinello, 2015), the mosaics were again excavated to assess the overall integrity and the state of conservation of the tiles, thus initiating a restoration process aimed at defining a solution that would allow the visitors to appreciate the original drawing of the Basilica.

On the sides of the central nave there are two large trapdoors through which it is possible to observe the fragments of the mosaic and appreciate the general layout, that measured about 16.36 x 6.80 m. The overall design had to present two distinct carpets: the first, to the west, of 6.50 x 6.80 m, with a series of intertwined medallions, acanthus leaves and plant motifs on a black background; the second, of 9.86 x 6.80 m, comprised six square panels adorned with geometric motifs and a wide range of colors.

finds correlation with that of research, in which the objectives of the analysis strategies correspond to the descriptive needs of the relationships identified for the characterization of the different levels.

[5] Since 2013, restoration has been carried out on the roofs, on the walls and on the mosaic complexes. The Dada-LAB Research Laboratory immediately collaborated with Piacenti S.p.A.

Since the central portion of the plant has been lost, it is possible to read only a few portions of the six panels belonging to the second carpet: the first one divides squares into swastika motifs; the second alternates octagonal figures with square shapes; of the two centrals it is possible to read only the upper one, representing a round medallion, with triangular and intertwined motifs, and the same medallion decoration is visible in the oriental panels, decorated with complex rings (Fig. 3). Further portions of the floor are visible in the easternmost area of the central nave, in the northern arm of the transept and in the south nave. These panels show plant and zoomorphic motifs on a white background and, in comparison with the carpet of the central nave, have free decorative layout without borders.

Qualitative differences are visible in the tiles layout: those that constitute backgrounds or borders are more spaced apart, while the designs, both geometric and organic, are made with smaller tiles, closer together. These density variations have conditioned the graphic restitution project. If, from one side, the greater thickness of the mortar between one block and the other facilitated the automatic recognition of the edges with the image vectorialization on the other side, due to more decorated areas, with a greater density, this procedure has been more complicated, also because of the chromatic variety that imposed a color coding.

Fig. 3: Details of the second carpet scores

4. *The mosaic drawing*

Following the acquisition phase, once the mosaics materic drawings were recomposed, the goal was to get a vectorial drawing where the minimum element was identified by a closed polyline, corresponding to the contours, differentiated in terms of layer in relation to the color of the tile[6].

The point cloud of the Laser Scanner survey was subdivided by materializing the mosaic partition, defined in the survey campaing during the shooting phase[7]. This process has facilitated the management of the post-production procedures and of the structuring of an orientation code of the different s useful for storing data.The entire mosaic apparatus has been recomposed through present equal ortho rectified portions of 15x15 cm, 30x30 cm or 45x45 cm, in relation to the complexity of the layout design and to the chromatic variations, rich in criticality for edge detection software (Di Blasi & Gallo, 2005).

Bitmap graphics softwares has been used, suitable for photo editing, integrated together to improve their functions (Monti & Maino, 2012) and using Adobe Photoshop and Lightroom softwares, the images were adjusted by changing the tonal values, exposure and the brightness[8].

Once the images have been optimized in terms of colors and contrasts (Fig. 4), different vectorialization software have been evaluated by comparing the time procedure and the result. Adobe Illustrator has been chosen for the possibility to interact with different formats both inbound and outbound. By adjusting the tolerance values, thresholds and traces, it has been possible to isolate the contours of the individual tiles.

Thanks to this, it has been possible to define the settings according to the different types of tiles, color, and the lighting conditions, which allowed to

[6] To improve the management of the levels, the color of the digital tiles is standardized with reference to the natural aspect, considering however all the present nuances.

[7] In order to obtain a high quality of the photographic data, during the survey campaing the mosaic was divided into portions of 15x15 cm, 30x30 cm and 45x45 cm (based on the complexity of the drawing) by affixing wires over tiles, arranged from side to side. This grid allowed us to codify each portion, photograph it separately from the others and obtaining images of great precision and sharpness.

[8] Working with the "curves" tool it was possible to adjust the color dominants for the tiles that had different balance and brightness for light problems that could not be solved during the acquisition phase.

automate the process thanks to the activation of precompiled actions.

On one side, the contrast between the dark tiles (that go from shades of red, to brown until black) channels the tonal values are transformed to make the tiles completely white and darken the mortar (Fig. 5). By importing the calibrated image onto Illustrator, it is possible to visualize only the edges

Fig. 4: Detail of the portion of source and modified orthophotos

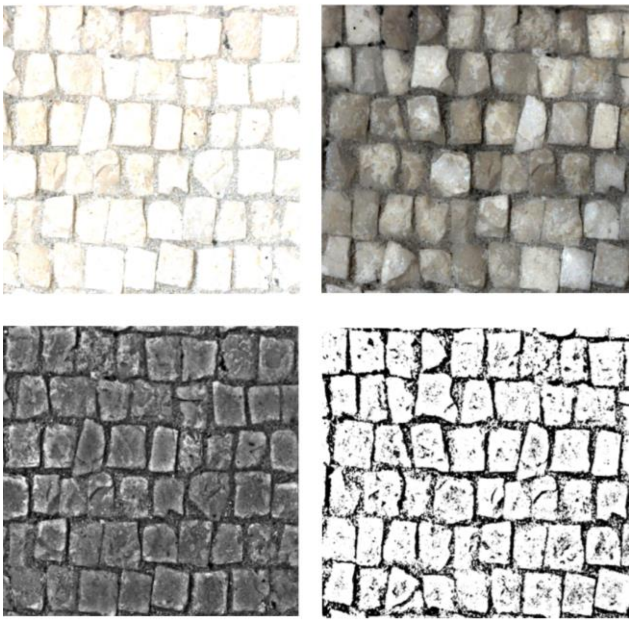

Fig. 5: The white tiles modified to improve the contrast of the edges

the mortar made the edges easily identifiable, on the other side, for the lighter tiles (from white to yellow, to ocher, to pink) the difficulty of vectorialization required a more complex image calibration phase. By changing the exposure, contrast and curves relative to the brightness values of the tonal range or the individual color

of the tiles (view contours), adjust the number of tracks and the disturbance (looking at the preview), increase or consider the percentage of corners (set a 0% for greater tiles cleaning,) through the "trace" tool. Last, it is necessary to raise or lower the threshold levels, which will be different for each file[9]. The vectorial image of each closed boundary tiles obtained can be exported as a dwg file and opened on AutoCad software. The file is constituted of Splines, which must be converted into Polylines to optimize the work in the subsequent phases.

It is necessary to consider that each tile, during the automated process, was traced with Spline overlays by the Adobe Illustrator software (according to the settings set manually) to ensure greater accuracy of the final result. This has generated a certain amount of duplicate elements in the dwg file that weigh it down in terms of file size (Fig. 6) (Parrinello & Picchio, 2019).

For each color of the tiles, a corresponding layer has been created to facilitate computations and to restore the mosaic representation, even with chromatic simplifications (Fig. 7).

The applied methodology has produced valid automation results, although in some cases it was necessary to integrate the design manually always working on the source photo by subtraction, eliminating the mortar from the images, selecting

[9] The procedure carried out on Adobe Illustrator for white tiles is the same as for colored portions. The difference is found only in the management of the threshold instrument: the setting of a higher threshold level enhances the portions that are better lit and the tiles with clearer colors; at a lower level corresponds a better reading of the dark tiles. It is therefore advisable to repeat the process several times, setting different levels, for each mosaic portion with a wide chromatic range.

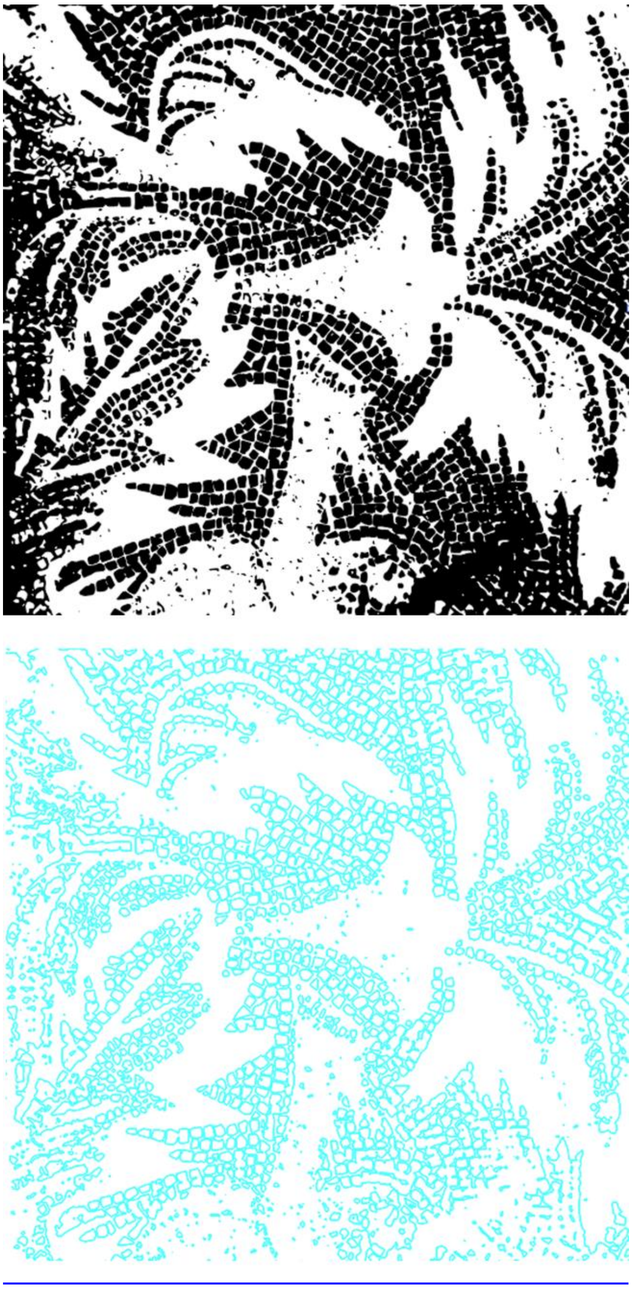

Fig. 6: Vectorialization process of the image in Illustrator

it or deleting it, to then proceed with automatic vectorialization (Figg. 8-9).

5. Tridimensional modelling

The mosaic drawings have an intrinsic 3D structure due not only to the tile itself, but also to the reciprocal position and orientation of these. The tiles together with the mortar, affected by the light, give rise to the visual perception of the mosaic complex (Rivola, Castagnetti, Bertacchini, & Casagrande, 2016).

This drawing perception, performed on a floor surface, is also due to the tiles non coplanarity and

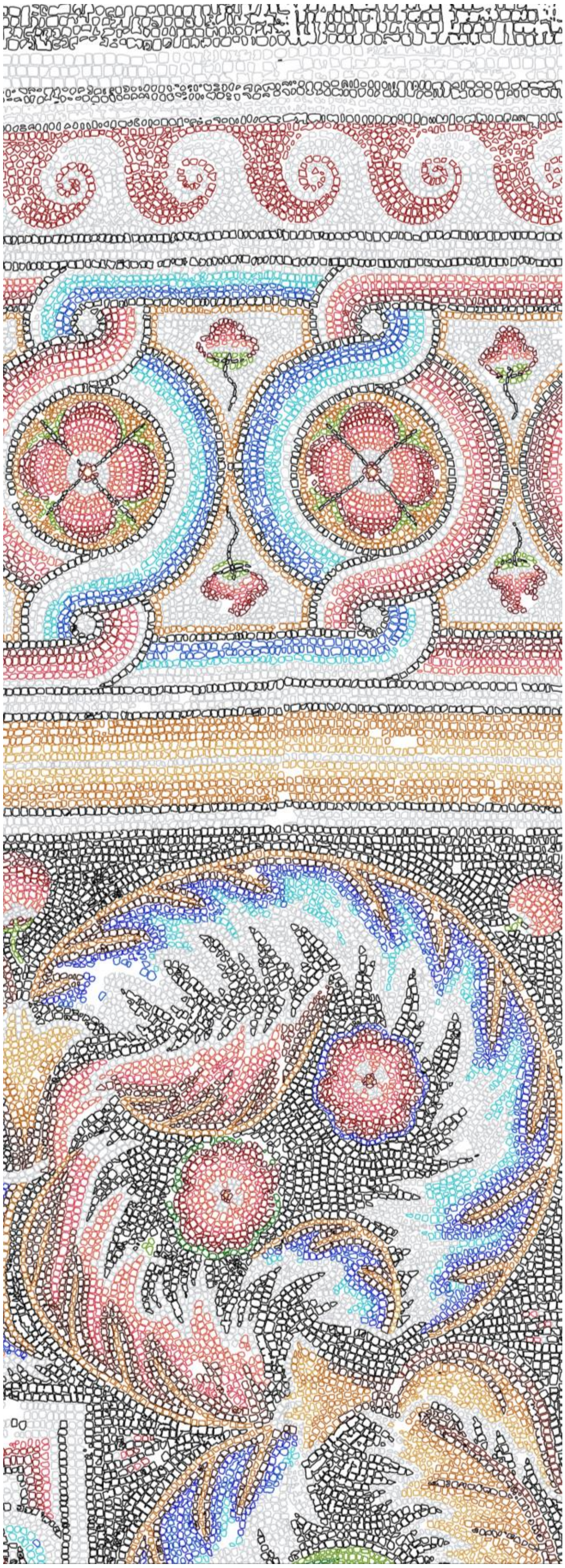

Fig. 7: Mosaic reproduced on AutoCAD

Fig. 8: Orthophoto and drawing of the mosaic reproduced on AutoCad

their inclination which produces light refraction effects. The thickness of this decorative apparatus, although minimal, needs to be represented to ensure a correct reading of the artwork.

The 3D drawing representation aims to highlight the cognitive data obtained from the mosaic documentation. Through this visualization it is possible to obtain immediate reading of the information content of the model itself. The researcher is thus facilitated in the understanding of the analyzed work, just as the restorer is facilitated in perceiving the information related to geometry and forms (Limoncelli, 2011).

Digital technologies offer important perspectives for the graphic rendering of historical-cultural value artworks. These technologies are valid especially when they are applied to artworks, such as the case study treated, not accessible to the public for conservative needs. Plants and general sections of the mosaic have allowed to return the information concerning the excavation (content, depth, width, length,

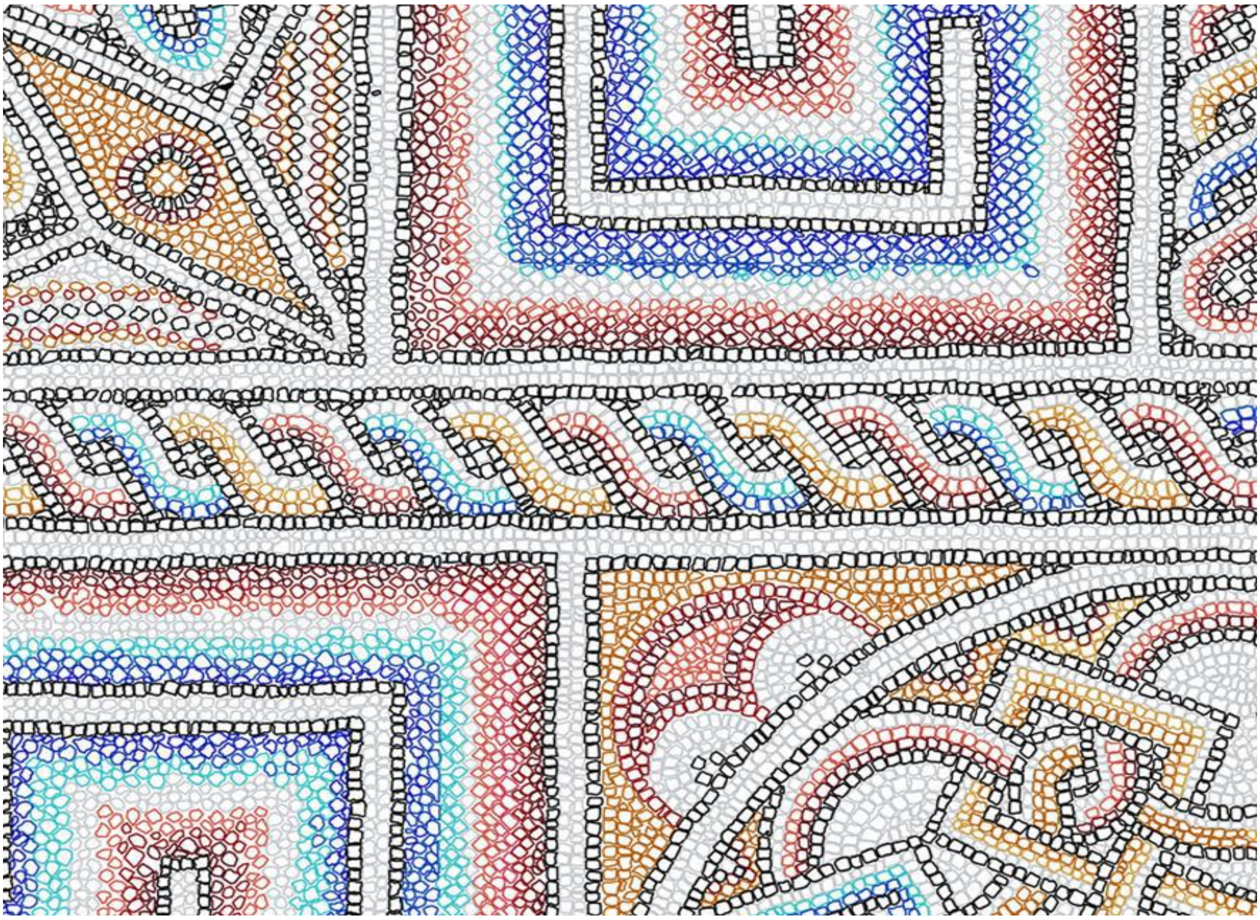

Fig. 9: Drawing of the mosaic reproduced on AutoCad

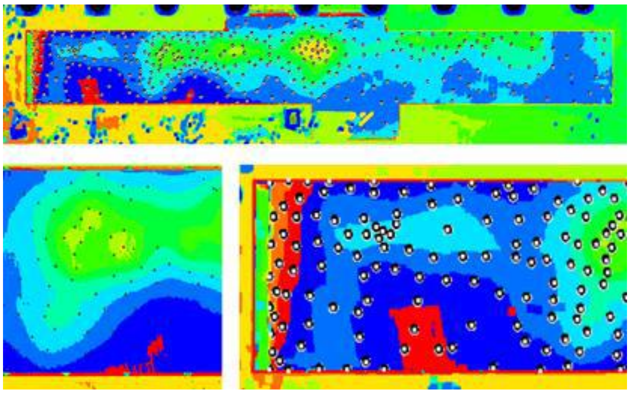

Fig. 10: Elevation map of the mosaic from the cloud of laser scanner points for the analysis of the height differences of the mosaic surface

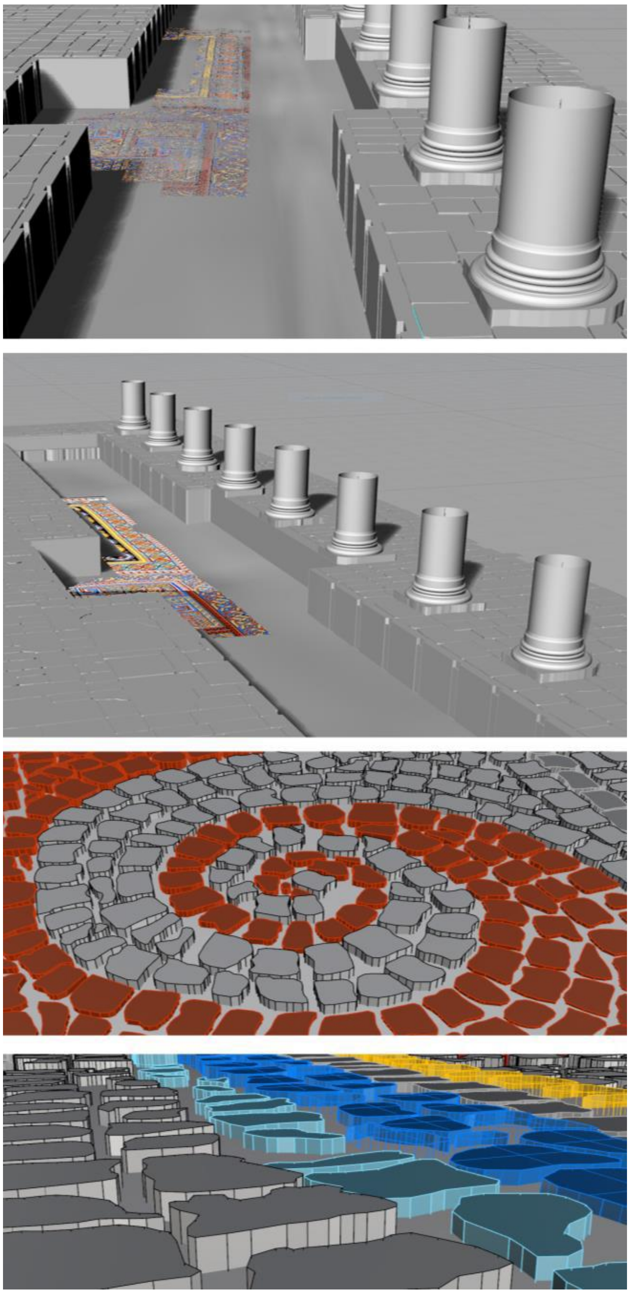

Fig. 11: 3D model of the mosaic

deformations, etc.) and these graphic drawings, imported on the Rhinoceros modeling software, have constituted the prerequisite for the development of a reliable prerequisite for the development of a reliable model system.

A first phase saw the return of the excavation and the laying surface of the tiles. The mosaic height differences were approximated using the "multipick" command from Leica Cyclone software and selecting over 290 control points from the point cloud. From these points a nurbs surface was reconstructed using the Patch command of Rhinoceros (Fig. 10).

During a second phase on this surface the tiles of the vector mosaic drawing were projected and extruded. The 3D graphic representation, based on chromatic intervals, provides defined and readable information on the drawing, position and quantity of the tiles present in the mosaic complex (Fig. 11). The choice of operating with the extrusion method, which involves the loss of information in terms of individual inclinations and deformations of the tile, has allowed us to obtain a 3D model useful for computation and effective representation of the artwork.

The union of the 3D model of architectural apparatus portion affected by the excavation with the mosaic tiles applied to the pavement, gives consistency to a digital object that is easy to read and interpret. The simplification made allows therefore a complete visualization of the apparatus and not only of some of its portions, bringing the further advantage of a much lower weight compared to that obtainable by modeling the single tile. The model, which is informative and communicative, can also be used for informative projects, as well as being implementable from the point of view of interaction, multimedia and virtual reality for digital use.

6. *Conclusion*

The two-dimensional (Fig. 12) and three-dimensional digital drawing created meet the need for computation and planning of restoration processes, maintenance control as well as being usable also for the creation of digital information archives. The digital models, or more often portions of them, can also find material concreteness, configuring themselves as specific communicative supports, to be realized with a view to a more inclusive use of the heritage (Rivola, Castagnetti, Bertacchini & Casagrande, 2016).

In this direction, some 3D prints of a portion of the mosaic were produced, evaluating the representative effectiveness on supports such as wood and plexiglass. The impression of the laser cut was defined by the pigmentation of the single mosaic tile and a lighter pigment (white tiles) corresponded to a smaller incision of the edge, while to the darker tiles corresponds a greater impression, to reach a depth of about 3 mm (black tiles).

The mosaic model can be configured as an additional opportunity for an independent and inclusive use of the work, developing tactile maps and relief models and preparing scenarios in which the mosaic can exit the basilica to characterize exhibition and installations, becoming an element that, between reality and virtual, manages to create new opportunities for knowledge.

Fig. 12: Detail of the portion of source and modified orthophotos

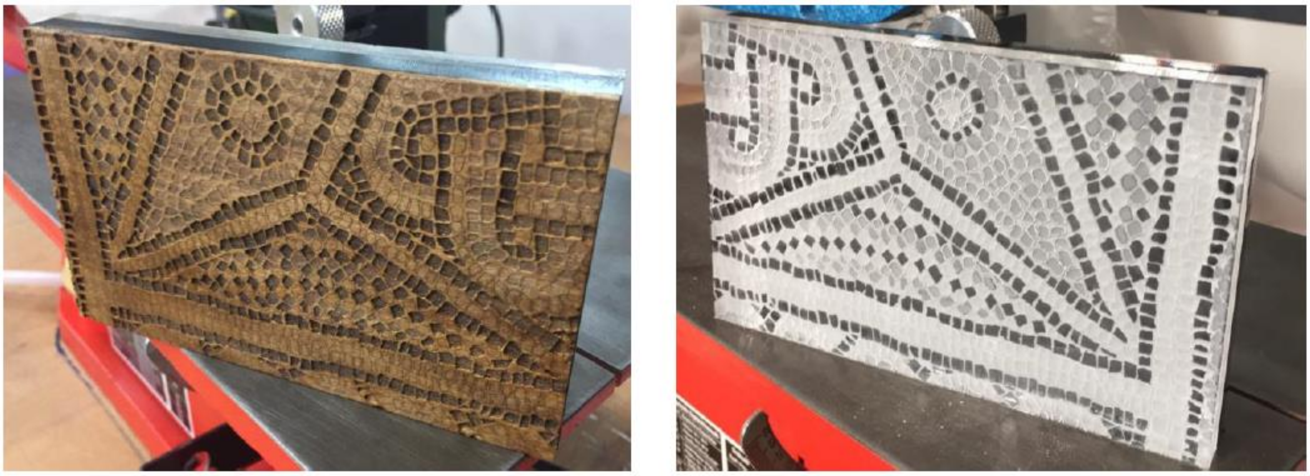

Fig. 13: 3D printing of the digital file

REFERENCES

Adami, A., Fassi, F., Fregonese, L., & Piana, M. (2018). Image-based techniques for the survey of mosaics in the Basilica di San Marco in Venice. *Virtual Archaeology Review*, 9(19), 1-20.

Bertocci, S. (2016). Porti e città fortificate in Terrasanta: modelli e tecnologie attraverso il Mediterraneo all'epoca delle Crociate. In G. Verdiani (Ed.), *Defensive architecture of the mediterranean XV to XVIII Centuries, Vol.IV*, (pp. 443-452), Firenze, Italy: DidaPress.

Bertocci, S., & Parrinello, S. (2015). *Digital survey and documentation of the archaeological and architectural sities*. Firenze, Italy: Edifir.

Brumana R., Fregonese L., Monti C., Monti C.C., Monti G., & Vio E. (2007). Complex analyses of surface, modelling and comparison of the 3D orthophoto to the real scale with historical cartography: mosaic surface of basilica of San Marco in Venice. *e-Perimetron*, 2(4), 224-244.

Cantisani E, Garzonio C.A, & Tucci G. (2006). Il pavimento della Cattedrale di Santa Maria del Fiore a Firenze: progetto di rilievo. In *Pavimentazioni storiche, uso e conservazione. XXII Convegno internazionale Scienza e Beni Culturali "Pavimentazioni storiche. Uso e conservazione".* (pp. 83-89). Bressanone, Italy: Arcadia Ricerche.

Fiori, C., & Vandini, M. (2002). *Teoria e tecniche per la conservazione del mosaico*. Padova, Italy: Editore Il Prato.

Limoncelli, M. (2011). Applicazioni digitali per l'archeologia: il restauro Virtuale. *DigItalia*, 1, 42-59. Retrieved from http://www.digitalia.sbn.it

Madden, A. (2012). *A Revised Date for the Mosaic Pavements of the Church of the Nativity*, Bethlehem, Israel: Ancient West & East.

Manferdini A.M. (2010). *Digital survey of ancient mosaics of Ravenna*. Proc. ISPRS Commission V Mid-Term Symposium 'Close Range Image Measurement Techniques', (pp. 434-439).

Monti, M., & Maino, G. (2012). L'informatica per il mosaico, tre casi prototipali. *Archeomatica,* 3(1), 22-27.

Norberg-Schulz, C. (1992) Genius Loci. Paesaggio, ambiente, architettura. *Documenti di Architettura.* Milano, Italy: Electa

Parrinello, S. (2013). *Disegnare il paesaggio. Esperienze di analisi e letture grafiche dei luoghi*. Firenze, Italy: Edifir.

Parrinello, S., & Picchio, F. (2019). Integration and comparison of close-range sfm methodologies for the analysis and the development of the historical city center of Bethlehem. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences,* XLII(2/W9), 589-595.

Rivola, R., Castagnetti, C., Bertacchini, E., & Casagrande, F. (2016). Digitalizzazione e stampa 3D di un mosaico a tecnica bizantina a scopo documentativo e conservativo. *Archeomatica*, 7(1), 34-37

Tucci, G., Bonora, V., Crocetto, N., Nobile, A., & Al Turk, L. (2010). Rilievi e documentazione di superfici musive a supporto del progetto di conservazione: il caso del Mausoleo del Sultano al-Zahir Baybars in Damascus. In *Proceedings of the First International Convention "Ravenna Musiva. Conservazione e Restauro del Mosaico Antico e Contemporaneo"* (pp. 441-451). Ravenna, Italy: AnteQuem.