Virtual reconstruction for a physical restoration: a virtuous approach

The case of a Roman mosaic damaged by World War II bombings

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The bombed mosaic from the former Fabbricotti collection at the Museo del Castello San Giorgio in La Spezia

The conservation treatment carried out on the fragments of a Roman mosaic from ancient Luni, now housed in the Archaeological Museum of La Spezia (Museo del Castello San Giorgio), Italy, raised several methodological issues and required a somewhat innovative approach.[1] The mosaic is referred to as Mosaic n. 2 of the «Fabbricotti collection» - after the name of one of its previous owners - and it was originally a polychrome tessellated pavement measuring about 2,43 x 2,53 m. It was broken into hundreds of fragments and partially destroyed in the wake of the heavy bombings that deteriorated its former conservation premise during World War II (Alessi et al. 2020). In its current state it can be considered as a ruin - a very significant condition in view of the theoretical approach to its conservation. The first part of the intervention aimed at identifying the fragments belonging to this mosaic among those kept in storage at the museum, in order to attempt a restoration of its surviving pieces. The only representation of the undamaged mosaic was a historical photograph dating back to the 1930s (fig. 1). Although no tools were specifically developed to carry out the reconstruction (in whole or in part) automatically, several digital techniques and tools were used to support the conservators' work in the manual search for the reassembling of the fragments[2].

The digital approach to the restoration process

1 This intervention was carried out in the frame of a graduation degree project at the School of Higher Education of the Opificio delle Pietre Dure in Florence, supervised by Francesca Toso, Marco Ciatti, Anna Patera, Andrea Cagnini and Fabio Fratini, whom we gratefully acknowledge.

The digitization of the fragments was carried out thanks to the collaboration of the academic spinoff of the University of Florence "Laboratori Archeologici San Gallo", composed of a team of medievalist archaeologists including Lapo Somigli.

2 Due to the purpose of the project and the intrinsic criticality of the case study, there were no conditions to develop tools that could automate the recomposition process (merely as an example, see Hernandez et al., 2019 and Riccio et al., 2015).

The intervention started out with a systematic analytical study and filing of the nearly 300 fragments taken from the museum storage. Then all the fragments were documented through a high-resolution photographic survey in order to obtain a 3D model of each fragment and orthophotos of all the tessellated surfaces, through stereoscopic photogrammetry techniques and processing of structure from motion.[3] The aim of the survey was not merely to generate a digital copy of the fragments, but it was primarily intended to provide the operational means to implement a digital reconstruction of the mosaic. The first step took place in a 2D environment: the orthophotos were used to find the original position of each fragment. This was achieved by overlaying these images on a background representing the photograph of the mosaic prior to its deterioration (fig. 2a). To obtain the most accurate result, the photograph was undistorted through photo straightening processes based on the mosaic's square frame and known dimensions.[4] This method allowed to determine the exact original position of 75 fragments, and to identify a suitable position for another 113 fragments. Subsequently, a 3D re-composition of the virtual models was undertaken, which ultimately provided a clear image of the actual material consistency of the mosaic's remaining entity, showing that it corresponds to about 40% of the original surface (fig.2b). It also showed that in this specific case it was possible to attempt an actual reconstruction of the surviving part of the artifact, thus allowing its future exhibition to the public.

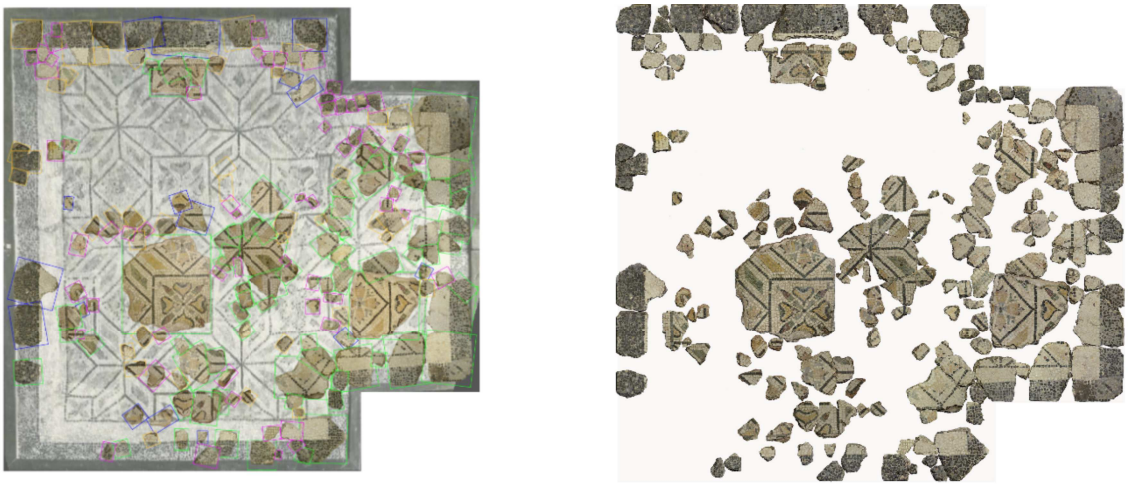
Fig. 1. The undamaged Mosaic n. 2 of the former Fabbricotti collection in a historical photograph published in Fabbricotti 1931

3 The software used was Agisoft Metashape. Photos were shot with a Nikon D-7100, 24.1 megapixel DX-format CMOS sensor and Nikkor 18-105 f/3.5-5.6 VR lens. 3D models were exported as PLY files and JPG textures.

4 The precariousness of the available data allowed to obtain an orthophoto with an error in the order of 2 cm, which was considered to be acceptable for the prefixed purpose.

The physical reconstruction of the mosaic

The virtual phase was hence followed by a physical one, where the fragments were placed onto a new support reproducing the original shape and dimensions of the mosaic. Each fragment was backed with a small stand and fixed on the support using re-closable fasteners, to allow possible rearrangements of those whose position was not positively identified. In case new data become available, both the virtual and physical reconstructions can be updated by editing the 2D and 3D models of the mosaic and rearranging the actual fragments accordingly. The fragments were then associated with a representation of the missing surface, printed on an aluminum composite sheet (fig. 3a), that fills the gaps and recreates a visual context without properly reintegrating the original artifact[5]. This exhibition device was entirely designed using the 3D model of the virtual reconstruction of the mosaic (fig. 3b).[6]



a *b*

Fig. 2. The digital reconstruction of the mosaic: a) 2D reconstruction with the orthophotos of the fragments overlaid on the straightened historical photograph of the undamaged mosaic; b) 3D rendering of the mosaic's surviving fragments.

5 On the use of synthetic materials for the conservation of ruins see Improta (2014).

6 The 3D virtual reconstruction of the mosaic and the design of the display device were carried out with the collaboration of Mattia Mercante, using the softwares Pixologic ZBrush and Autodesk 3D Studio Max.

Conclusion

During this intervention the photogrammetric data proved to be an essential tool not only in the preliminary digital phase, but in the following parts of the restoration as well, providing a means to present the mosaic efficiently in a museum display without concealing its current fragmentary state. In that sense the digital modeling allowed to give a physical context back to the fragments by re-establishing their legibility. Moreover, having designed a stable yet unclosed solution for the setting of the actual fragments on their new support, leaving the possibility for further rearrangements open, the digital reconstruction may still play an active role in the intervention in spite of its apparently auxiliary function. Although this experimental study on the use of digital tools in the conservation of cultural heritage originated from the specific need to physically restore the surviving fragments of the Mosaic n. 2, the adopted procedures can find broader applications in the development of new methodologies in the restoration of fragmentary artifacts. At present, once the physical phase of the reconstruction is completed, various research perspectives remain open in two main directions: on one hand in the use of digital tools for the physical restoration of fragmentary artifacts and on the other hand in the development of applications that can enrich the fruition of the artifacts in museums. As to the former, possible developments include programming tools that at least partially automate the repositioning process, which could be achieved through the recognition of the decorative features or by detecting possible matches in the break surfaces between the fragments. In addition to that, in the case of the Mosaic n. 2, the existence of a photograph of the original state of the artifact prior to its deterioration and the discrete nature of the tessellated surface would potentially allow the single mosaic tiles to be used as atomic elements, comparable to pixels. A procedure based on the use of photographic data can significantly be extended to all those artifacts that are increasingly damaged by human or natural catastrophic causes, though it excludes an application on fragments discovered in archaeological excavations.

a b

Fig. 3. Details of the physical reconstruction of the mosaic showing a) the fragments and the aluminum sheet displaying the missing surface, b) the set up in progress.

As regards the second area of research, prospective ideas involve the development of multimedia or interactive contents and devices as edutainment experiences to enrich the museum display of the mosaic. In particular, the virtual models (textured meshes of all the fragments on a 1:1 scale, already correctly placed in space) could be used to design an animation replicating the repositioning process of the fragments. For instance, the animation could start with a view of the fragments stored in boxes progressively "brought to life" and positioned on the empty frame of the mosaic. This product, accompanied by detailed texts, pictures and videos explaining the various phases and showing the full process of the conservation work, could facilitate the viewers' understanding of the restoration. Another potential idea involves the creation of an interactive app with which the visitor can try his hand at recognizing correct positions of the fragments, just like in a puzzle, starting from a two-dimensional background on which the decorative motifs of the mosaic are traced. The aim would be to make visitors understand both the technical and interpretative issues addressed during the conservation work and therefore to enhance the scientific and methodological criteria that lead the reconstruction. The app could show a 3D view environment in which the decorative motif of the mosaic is represented in the background; the user could choose from a selection of the main fragments and try to position them correctly in space, with simple and intuitive rotation and translation tools on the plane. The application could provide the user with positive or negative feedback and suggestions on the reconstruction. Products of this type could be useful in improving the fruition of the museum exhibition by several levels of visitors (children, adults and specialists), and could also allow to develop the engagement of the public through the online presence of the museum (replicating the systems on web-based platforms), now more than ever encouraged by the pandemic situation of recent months.

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