



# Challenges in the digitisation of a high-reflective artwork

C.E. Catalano<sup>1</sup> , E. Brunetto<sup>1</sup>, M. Mortara<sup>1</sup>  and C. Pizzi<sup>1</sup>

<sup>1</sup> Istituto di Matematica Applicata e Tecnologie Informatiche "E. Magenes", CNR, Italy

## Abstract

*In this paper we report about the photogrammetric acquisition and reconstruction of a contemporary artwork, performed by off-the-shelf software. The ceramic piece of art is "Il Libro d'Oro del Terzo Paradiso" ("The Golden Book of the Third Paradise") by Michelangelo Pistoletto, accessed and studied in the framework of a regional project. This artefact is particularly challenging. On the one hand, it is golden coated and, as such, highly reflective. Hence, images are likely to suffer from highlight spots, shadows or self-reflections, and the reconstructed point cloud is typically noisy. On the other hand, the object exhibits simple geometry, mainly composed of planar surfaces, and is highly symmetric; however, it possesses detail features and undercuts. The symmetric nature of the object and reflections misled the image alignment, and the noise in the data turned out to be of the same scale as the detail features. We will discuss all the steps of the process, aimed at obtaining a high quality and accurate 3D model using low-cost tools.*

## CCS Concepts

• **Computing methodologies** → *Mesh models; Texturing*; • **Applied computing** → *Arts and humanities*;

## 1. Introduction

Digital Heritage, and digitisation of cultural artifacts in particular, are widespread in the community. In the last fifteen years, several acquisition campaigns have been carried out (surveys, buildings, statues and artifacts) for different purposes [ED06]: for digital visualisation, documentation and conservation [SCD\*17], for a better and more engaging communication of Cultural Heritage (CH), and for the interpretation of cultural assets by means of computational tools and digital measurements (e.g., [TBF18]).

This trend was beneficial both for Computer Graphics (CG) and CH: at the beginning, computer scientists offered their expertise to guide the acquisition process, support the 3D reconstruction and geometric processing. Then, CH offered challenging use cases (e.g., archaeological surveys, composite materials, virtual reconstructions of incomplete objects), which improved the efficiency and effectiveness of computational techniques (e.g. multi-spectral images, Reflectance Transformation Imaging, 3D shape analysis).

Nowadays, 3D laser scanners and photogrammetry are common technology for acquisition in the domain [CS08] [MSE\*10]. The choice between the two depends on the context of use (e.g. data precision, digitisation time) and the available devices for the single projects. However, thanks to the maturity of digitisation, today CH practitioners are directly involved in 3D scanning and are used to dedicated software.

The goal of this work is to tackle the reconstruction of a precious artwork by testing low-cost tools, such as digital camera and free off-the-shelf software [Kin20]. The reason is twofold: on the one

hand, we intended to experiment devices and techniques within the reach of CH operators, and not only of CG experts; on the other hand, we aimed to appraise the usability of such tools and the visual accuracy of the resulting 3D model.

The case study stems from the collaboration with the Savona ceramics museum in Italy in the framework of the INTER-CH regional project, whose objective is an effective communication and consumption of cultural heritage by innovative physico-virtual interaction technologies [RBB\*20]. The artwork is named "Il Libro d'Oro del Terzo Paradiso" ("The Golden Book of the Third Paradise") by the contemporary artist Michelangelo Pistoletto. Despite its simple geometric shape, the acquisition of this object posed a challenge because of its high reflectivity.

It is well-known that shiny and transparent objects strongly compromise the performances of the reconstruction process with any acquisition device [IKL\*10]. Several ad-hoc solutions have been provided and some focussed on the acquisition by 3D laser scanners ([OSP\*10] [ABVT13]). If using photogrammetry, reflective surfaces generate confusion in the location of reference points in the photos, since lights constantly change. This causes a failure in the image alignment and the occurrence of noise artifacts in the final data [WK15] [WZQ\*18].

As a consequence, this case study presented several technical issues, which required a precise planning of the acquisition sessions for both geometry and textures, and a laborious reconstruction of the artwork in order to achieve a high quality and accurate 3D model.



**Figure 1:** Two images of the original artwork where the symmetrical shape and strong reflectivity of the object may be noticed. A craquelé pattern is also present throughout the surface.

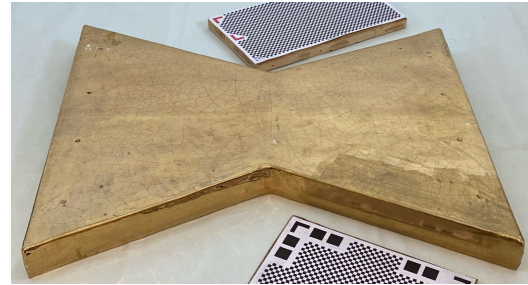
The paper is organised as follows. In Section 2, the case study is illustrated and the acquisition pipeline sketched. Section 3 describes the acquisition and reconstruction process, while Section 4 discusses the texturing process, showing a final rendering of the 3D model obtained. Section 5 concludes the paper.

## 2. Il Libro d'Oro del Terzo Paradiso

The artwork "Il Libro d'Oro del Terzo Paradiso" by the contemporary artist Michelangelo Pistoletto consists in a ceramic artifact coated with gold. As it can be seen in Fig. 1, it represents a book with a symmetrical shape that may look like a hourglass, and derives from the transposition of Leonardo Da Vinci's Vitruvian man. The surfaces are mainly planar: the top surface includes the incision of the Pistoletto's "Third Paradise" symbol, while the bottom one has no decoration but exhibits eight small pierces, due to the production process of the artwork (Fig. 2). The "Third Paradise" symbol has been conceived by the artist as a reconfiguration of the mathematical sign of infinity: it is composed of three consecutive circle-like curves in which the two outer curves represent the diversities and antinomies, such as nature and artifice, and the central one (the Third Paradise) represents the balanced connection between the two opposite ones [Thi]. The entire surface of the artwork is characterised by a *craquelé* pattern, i.e. small surface crackles of negligible depth (they cannot be felt by touch), formed during the baking process of ceramics (Fig. 1). Since the work represents a book, one of the four lateral sides is the book spine and is slightly curved, while the other three have an indentation for the pages. The book is 510 mm long, 430 mm wide and 45 mm high.

The acquisition of the artwork was challenging because of the significant reflectance of the gold coat, which causes frequent overexposed areas in the acquired images: point detection becomes very difficult in those areas and, as a result, the 3D geometrical reconstruction is compromised; the highlights also affect the reconstruction of the texture, which does not result consistent with the real colour of the original artwork. Moreover, the indented sections are affected by shadows of the protruding borders, and require a suitable capture angle to acquire areas that would remain hidden otherwise.

Due to the complexity of the object, we planned two acquisition sessions: the first session and the consequent reconstructed model were useful to understand the best camera and location setup; the captured images were used both for a first geometric reconstruction



**Figure 2:** The back of the book where there are the eight little construction pierces, arranged horizontally, four in the top side and four in the bottom one. This photo has been taken during the first acquisition trial, in which we used only two markers and we tested the matting agent (applied only in a little area on the right bottom corner).

and an initial test for generating the textures, arising the main issues (e.g., parts that were not sufficiently acquired, the details needing more attention). In the second acquisition session we collected the definitive photo sets.

For both sessions, images for textures and geometry reconstruction were captured in two different modalities and photographic settings. To face the reconstruction process, a layer of matting agent has been applied on the surface to minimise reflections. Since the golden coat of the artwork may be damaged very easily, the opacifiers typically used in photogrammetry (e.g., specific sprays) could not be used in this case. Then, we were supported by a restorer, who devised to apply a mixture of Marseille soap and water, dried on the surface. This agent is easily removable and does not damage the ceramic book. The opacifier was applied with a brush and the brushstrokes stayed visible, causing an alteration of the surface (Fig. 3). Clearly, the pictures of the matted artwork could not be used to reconstruct the texture.

In the second session, we firstly acquired images for the texture without the matting agent and then, after applying it to the entire artwork, we took the pictures for the geometric reconstruction. Because of the high value and fragility of the artwork, we were not allowed to touch it, but we could only interact with it through the restorer, who regularly cooperates with the museum.

In the following sections, we describe the acquisition operations in reverse chronological order, i.e., the acquisition for geometric reconstruction and the acquisition for the texture, respectively. In order to optimise the photogrammetric outcome, we needed to minimise reflections in the scene to capture reliable images. Therefore, a lot of attention was paid to select the best object and camera position, light settings and camera settings (i.e. ISO, shutter speed, aperture size, HDR modality and use of correction filters). We also tried different colours for the background and base for the artwork.

## 3. Acquisition and reconstruction process

Adopting photogrammetric techniques, the following steps were performed:



- *Object preparation, location setup and camera settings for acquisition*: the aim of this first step is to acquire good images for the geometric reconstruction. We applied the matt layer to limit reflections as much as possible and we tested different configurations for the mutual positions between the camera and the object, for the location setting (e.g., the ambient lights and the colour for the background cloth) and for the camera (i.e., lens type, aperture, shutter speed, and ISO settings).
- *Photo alignment*: this process is crucial in order to reconstruct the 3D scene and it consists in detecting the same features in multiple images; for this phase, we tested two free software, *Metashape* [Met] and *3DF Zephir* [3DF]; we achieved the best results with *Metashape*, hence we adopted it for the whole reconstruction process. The software proceeds detecting the same key points in two or more images, combining the camera orientation data (translation and rotation) with the shooting parameters (like camera focal length or lens distortion coefficients). Parameters from different images including the same key point allow to devise its 3D coordinates in the reference system. The outcome is a sparse point cloud.

Because of the symmetry and colour homogeneity of the artwork, initial tests in the alignment process failed in terms of number of registered photos; in order to break the symmetry and enhance alignment results, markers were positioned near the object. We also excluded some images affected by light reflections.

- *Dense cloud generation and mesh reconstruction*: starting from data extracted from overlapping image pairs, for each camera a *depth map* is generated; more points are added to the sparse point cloud by combining multiple depth maps, transforming them into partial dense point clouds. They are then merged into a final dense point cloud and an additional noise filtering step was applied in the overlapping regions. The resulting dense points cloud is the base for the 3D mesh reconstruction. Since the point cloud includes all the scene points, both belonging to the artwork and to the background, it was necessary to clean up the point cloud before starting the reconstruction process.

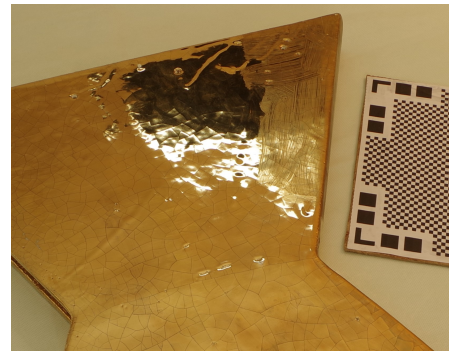
*Metashape* is able to reconstruct polygonal models providing several parameters to set the desired mesh quality; these are:

- the source data: sparse point cloud, depth maps or dense point cloud;
- interpolation: if it is enabled, *Metashape* uses interpolation to cover automatically some holes; oppositely, a manual hole filling could be required at the post-processing phase;
- face count: sets the maximum number of polygons in the final mesh.

We used the default parameters (dense point cloud as source data, interpolation modality enabled) to maximise mesh quality, despite a longer processing time.

However, this produced a model with a massive number of vertices, then, we set the maximum face count to 2 millions; this was a good compromise between quality and ease of manipulation in the following phases.

- *Post-processing operations*: the reconstructed 3D model exhibits noisy surface areas, small disconnected components, holes and other geometric and topological defects; therefore, it was necessary to clean and repair it by removing excess parts, repairing incorrect areas and smoothing the noisy areas. The latter is a par-



**Figure 3:** The matting agent applied in a small area on the lower side of the artwork; it should be noted the difference between areas with the opacifier (on the right) and without it (on the left). The brushstrokes are evident.

ticularly delicate operation, since the artwork exhibits tiny features and it is necessary to eliminate defects without losing any real details. For this task, we used the following free software:

- *MeshFix* [Mesa] to fix automatically geometrical and topological errors;
- *ReMESH* [ReM] to eliminate disconnected components and repair incorrect areas;
- *MeshLab* [Mesb] for local and global smoothing.

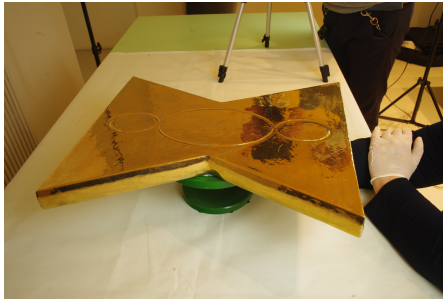
It has to be noticed that we treated photographs related to the upper half and lower half of the object separately. All the pipeline mentioned above, from the photo alignment to the dense cloud generation, was applied to each photo set; then, a single 3D model of the artwork was created implementing a merging procedure of the two separate dense clouds. More details will be given later in section 3.3.

### 3.1. Preliminary settings and image acquisition

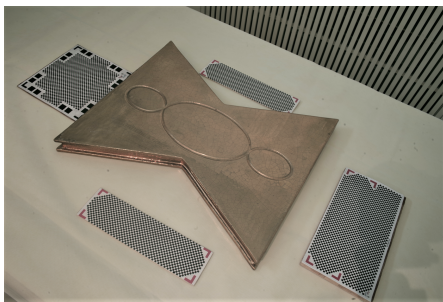
In this section it will be described how we set up the preliminary environment around our case study and specify the camera settings adopted in order to capture the best possible images for the geometric reconstruction. As already mentioned, a layer of opacifier was applied before shooting photos to be used for the geometric reconstruction process (Fig. 3).

Two different acquisition methods may be used. In the first one, the position of the camera is fixed and the object moves on a rotating table; here the artwork was rotated by about 15 degrees with each shot in order to capture the object from many different angles (Fig. 4). In the second one, the object remains stationary and the camera moves around it. In the first acquisition session we tried both these methods and the turning table led to unsuccessful alignment in terms of number of correctly registered images.

In general, it may happen that background objects are captured in the image, which should then be discarded. This issue especially applies to the turntable modality, because the support structure is usually captured with the object, and moreover, the background be-



**Figure 4:** The artwork placed on a turning table, rotated by the restorer. In the first experiment we tested this particular configuration, which was then discarded due to unsatisfactory photo alignment.



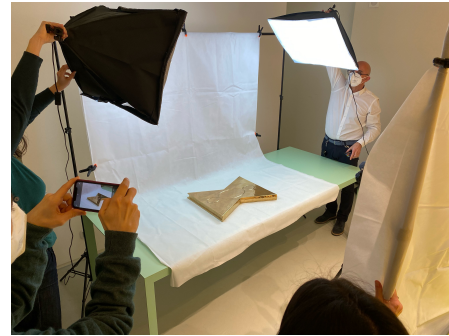
**Figure 5:** The artwork in a static position, placed on a support table with a white background cloth. Four markers were positioned near the object in order to enhance key point detection and correspondence.

hind remains fixed and can bias the search for corresponding points in the alignment phase.

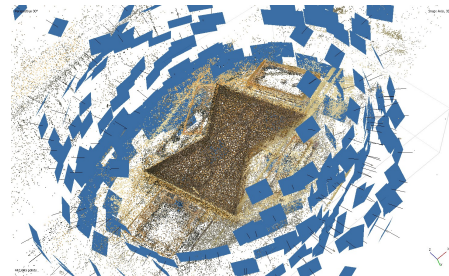
We proceeded applying masks (i.e. selecting relevant areas to maintain and discarding background to remove) testing both *3DF Zephir* and *Metashape*; the first one provides a fully automatic process (through the external tool *3DF Masquerade*); conversely, with *Metashape*, a more time-consuming manual or semi-automatic procedure is necessary to remove the background. Despite the masking process, the alignment process failed, probably because of the strong artwork symmetry with no additional hints. We therefore chose the setting of moving camera around the object setting, with the addition of four markers placed near the artwork (Fig. 5). In this case, the background removal was performed before the reconstruction from the dense point cloud.

The artifact and the markers were positioned on a table covered by a cloth. We tried both a black and a white cloth, but the images captured with the black background suffered from a dark reflection on the artwork. Oppositely, the white cloth was useful to create a good contrast between the object and the background and we finally opted for it (Fig. 6).

Regarding light settings, we placed two spotlights close to the object in order to produce a strong, diffuse and uniform lighting. During the shooting, we moved the spotlights (or one of the two



**Figure 6:** The location setup regarding photo acquisition for geometric reconstruction: the artwork was placed on a support table covered with a white background cloth; in addition, two spotlights were positioned around the table.



**Figure 7:** Camera positions in a circular sequence are shown: the images are related to the merged dataset, obtained by the union of the upper and the lower one.

spotlights) around the table until the reflections disappeared; with particular camera angles, we needed to switch them off.

Finally, we used a Reflex camera with fixed lenses (16 mm and 28 mm), low ISO value (100) and a quite large f-value (f11 - f13), in order to maintain a certain depth of field while keeping all the points in focus. It was necessary to use high exposure times in order to obtain images with a well-calibrated lighting, but a tripod and a shooting remote control were also used to avoid blurred pictures. In addition, a circular polarising filter was mounted on the camera lens to help reduce unwanted reflections.

The photos were captured in a circular sequence and at different heights: in particular, photographs were taken on four orbits at different levels; starting from a height equal to the support table the tripod was raised by about 15 cm at each successive step. In Fig. 7 it is possible to see camera positions in the sparse point cloud. For each orbit, the photos were taken in a circular sequence by rotating the position of the tripod by about 15° at each acquisition in order to obtain an overlap of 10-30 % for each image. Moreover, we took some very close-up photos in which not all of the object was in the frame, but taking care to capture at least one of the 4 markers (or part of it) and detect better lateral edges. The acquisition procedure was repeated by placing the artwork on both sides, the upper and lower one.

### 3.2. Photo alignment and dense cloud generation

Once the images were acquired, the alignment process started. In the first session, images were processed using both (*3DF Zephyr* and *Metashape*), but *Metashape* (limited time trial version) provided better results, leading to the registration of a much greater number of photos, and we opted for it. Regarding the alignment process, we imported about 190 photos for the top side and 170 for the bottom side, then *Metashape* was able to record 175 and 155 images for the two sides, respectively. To achieve this result, we set the "Accuracy" parameter as "highest". In this way, all the source photos are upscaled and *Metashape* is able to localise more common points between different images. As a result, the alignment process is improved, despite a considerable increase in processing time.

At the end of the alignment process, we obtained two sparse point clouds (upper and lower parts) from which, through the software automatic process, the corresponding dense clouds were generated. Note that the two dense clouds contained both the points related to the artwork and the background, which was removed: the upper dense cloud initially counted about 140 millions points, decreasing to 36 millions after the background cut; similarly, the number of points of the lower dense cloud, dropped from 240 million to 58 million. This cut operation is a first manual rough cleaning of the background and was repeated also in the successive phases.

### 3.3. Merging the point clouds

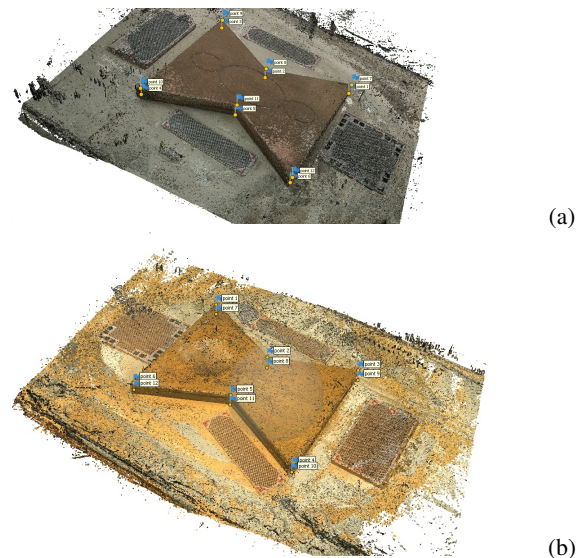
In order to achieve a 3D model it is necessary to merge the two dense clouds and then proceed to the mesh reconstruction. *Metashape* provides efficient functions to join different point clouds: 12 corresponding *control points* were manually selected (in the corresponding positions) in both point clouds (Fig. 8).

The lateral parts of the artwork were included in both point clouds; we decided to select the common areas from the upper cloud, since they were better reconstructed there. In case of missing data due to the undercuts, we selected small portions from the opposite point cloud to minimise the impact of occlusions.

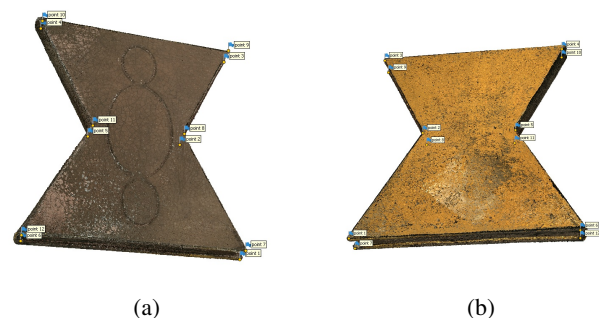
The merging process produced a single dense cloud of about 72 millions points (Fig. 9), which was further reduced to remove outliers not belonging to the artwork before the mesh reconstruction.

### 3.4. Mesh reconstruction and post-processing operations

Starting from the single merged dense point cloud (Fig. 9), the mesh reconstruction procedure was performed in *Metashape*: we used the automatic algorithm with ultrahigh quality, which permits to process original photos, without downscaling them. We decided to keep the default settings of the parameters except for the maximum number of faces for the final model. Without any constraint, the resulting mesh had about 14 millions faces and 7 millions vertices; therefore, we decided to set the maximum number of faces up to 2 millions, which provided a very dense mesh considering the morphology of the considered artwork. The default procedure includes also an interpolation algorithm which fills some preliminary holes due to the noise in the point cloud. As it is shown in Fig. 10 the final 3D mesh still presented some roughness; we then started



**Figure 8:** The two separate dense clouds of the upper (a) and lower (b) sides, respectively. These point clouds still include the background (markers are also visible), which was removed before the merging procedure. Note the control points in the two separate clouds, placed in the corresponding positions to allow the merging process.

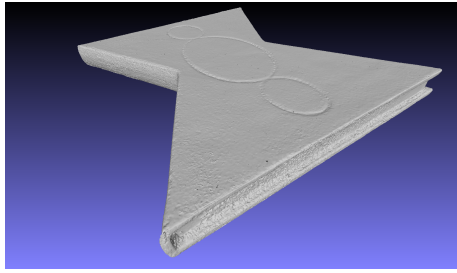


**Figure 9:** The merged dense cloud seen from both the top (a) and bottom side (b). The control point are still visible.

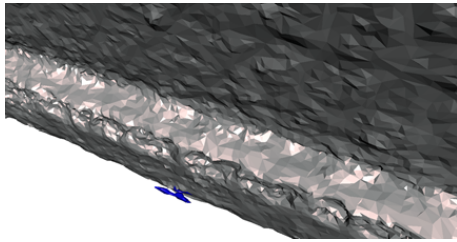
a long post-processing task in order to reduce noise and repair the model, maintaining accuracy as high as possible. The critical issue here was that noise had the same scale as the dimension of the features (i.e., the incised symbol of the Third Paradise and the small pierces on the back side). To distinguish feature points from noise we proceeded by visual inspection and comparison of the images and by local and manual repairing, performed balancing accuracy and processing time.

The geometrical and topological errors were fixed by the free software *MeshFix* [Mesa], which consists in an automatic procedure able to convert a raw digitised polygon mesh to a clean mesh, in which all the occurrences of holes, self-intersections, degenerate and non-manifold elements, are corrected and replaced by



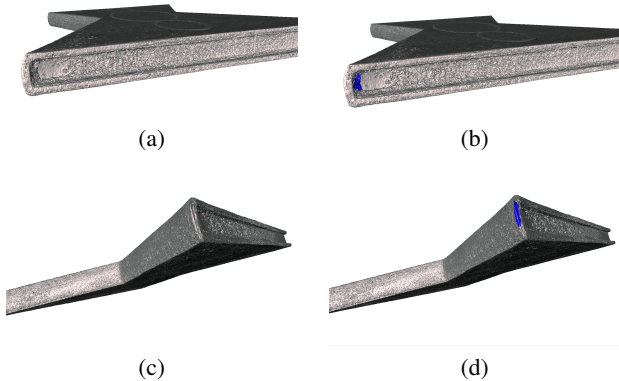


**Figure 10:** Noisy model before post-processing operations.



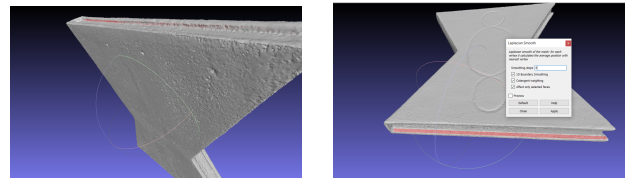
**Figure 11:** Image taken from ReMESH software: outliers are highlighted in blue colour.

valid configurations. Then, we used *ReMESH* [ReM], an editor for manifold triangle meshes with advanced repairing features; this free software was useful for removing some outliers of the mesh (Fig. 11) and for repairing noisy areas (Fig. 12).

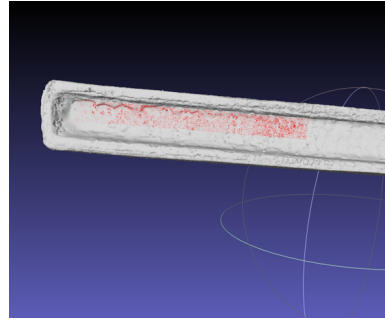


**Figure 12:** Areas with incorrect geometry to be repaired: noisy areas (a) (b), and outliers (c)(d).

Finally, we applied local and global Laplacian smoothing using the free software *MeshLab*. First, we applied the smoothing tool (iterating several times) only to specific rough parts, like the small edges under the main surfaces (Fig. 13) or single parts internal to the lateral sides (Fig. 14). Secondly, we applied the Laplacian smoothing to the entire model but preserving the features on the two planar surfaces, i.e. the "Third Paradise" symbol and eight small manufacturing pierces. Here again the operation was tricky,



**Figure 13:** Selection of noisy parts on the small edges under the main surfaces. Those parts are particularly noisy because they suffered from undercuts during the acquisition process.



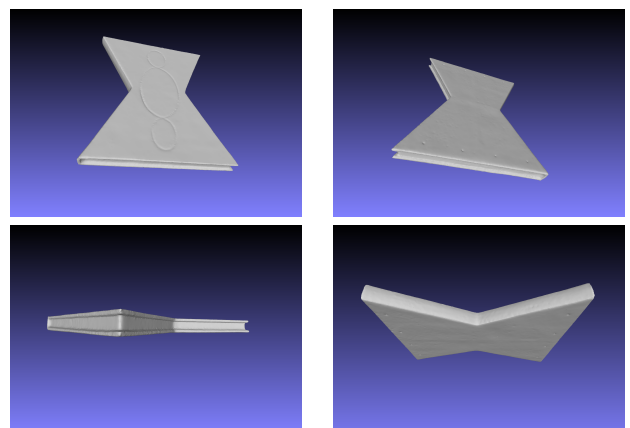
**Figure 14:** A noisy area on the lateral side to be smoothed.

since the features size is approximately equal to the error size. Fig. 15 shows the final mesh; note that some roughness was maintained in order to preserve the artwork real features.

## 4. Texturing process

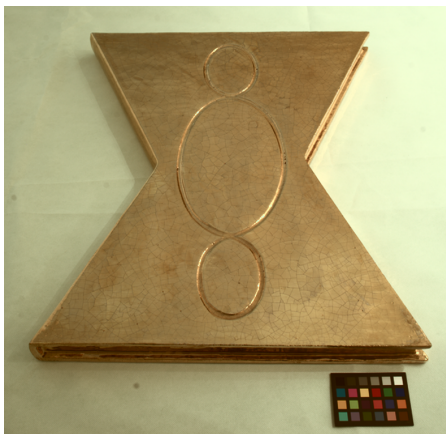
### 4.1. Acquisition

As mentioned above, photos for textures were acquired in the earliest stages of the pipeline. The photos were all taken in HDR (High Dynamic Range) mode, which is particularly suitable for preventing light reflections, and able to capture both the highlights and the shadow details.



**Figure 15:** The final reconstructed 3D model of "The Golden Book", from different viewpoints.





**Figure 16:** Surface acquisition for texture reconstruction: the artwork position is static. A colour-checker card was placed near the artwork in order to support real colour recognition during the photo processing.

The two main surfaces were captured by placing the artwork on the support table covered with the white background cloth; the tripod was set up in order to capture images almost perpendicularly; it only took a few photos to get the images for the two surface textures.

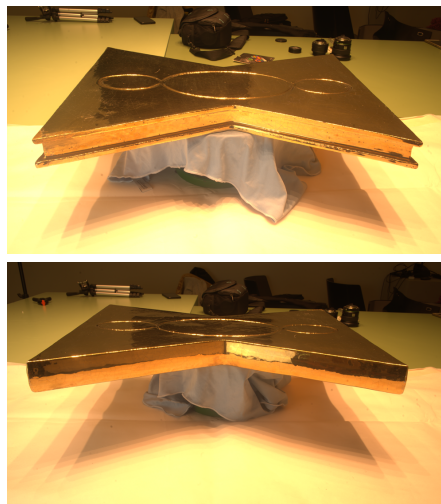
To cope with the lateral edges, the artwork was positioned on a rotating plate, to keep it raised 20 cm from the table top; this helped to minimise the reflections on the small edges due to the support surface (Fig. 17 (a)). Shooting the images to capture the lateral portions was particularly challenging due to the shadows, which often formed whole dark areas, as it may be seen on the book spine in Fig. 17 (b). In these cases several photos were needed for the same areas, which have been merged during the texture reconstruction phase.

Also in this phase, the artwork was positioned on both sides to acquire the undercuts. Because of the strong brightness of the object, it was not simple to identify the real colour in the captured images and we opted for a colour-checker card, a cardboard-framed arrangement of 24 squares of painted samples, which permits to recognise and calibrate colours in the acquired images (Fig. 16).

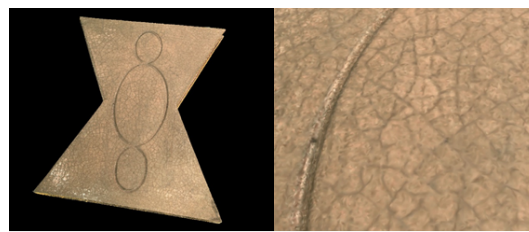
#### 4.2. Texture mapping

The object reconstruction returned a 3D model with per-vertex colour, but the overall result appeared unsatisfactory with distorted coloration and low definition details (Fig. 18). This particular issue held using both *Metashape* and *3DF Zephir*. Indeed, the final model required a trade-off: despite being acquired with a uniform and diffuse illumination, the photos had numerous reflections and significant colour variations caused by the extreme brightness of the artwork.

To achieve a more accurate result, the texture mapping technique was used, where one or more two-dimensional images are projected onto the surface of the 3D model. To define how the 2D textures wrap the associated surface, a parameterisation by UV map-



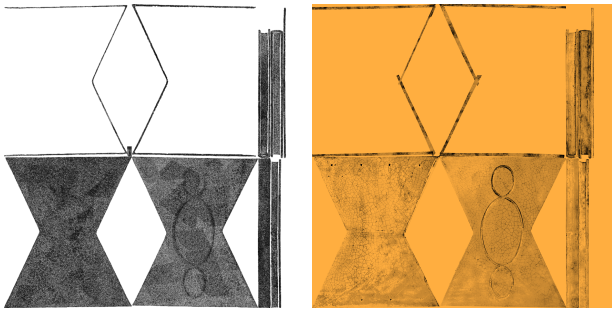
**Figure 17:** Acquisition of lateral texture. Reflections on the lateral edge are minimised (a); shadows and reflections appear on almost half of the book spine, because of its curvature (b).



**Figure 18:** The 3D model with colour on mesh vertices.

ping coordinates is generally used. UV mapping can be performed with various softwares and using different techniques, depending on the complexity of the morphology of the object. Models with high curvature and non-zero genus require mappings composed of a high number of cuts and large deformations: this makes texture overlaying very complex and affects the quality of the final result. For this reason, the UV mapping is almost always implemented in semi-automatic ways, often letting the user the task of subdividing the surface and positioning cuts opportunely. 3dsMax [3DS], Cinema4D [Cin], Zbrush [ZBr] are among the best commercial softwares to produce UV mappings, while Blender [Ble] represents the obvious choice as far as open source softwares concern.

We opted for Blender to generate the UV mapping, not only because it is open source, but also because it includes a fully automatic mapping functionality, which works very well when the surface of the model does not have high curvature, as in our case study. The Blender automatic *SmartUVProject* [Sma] mode allows the user to set a number of parameters, including a limit angle which is used to split the surface. In general, if the limit is high, more cuts and less distortion will be produced in the textures. This method works very well with flat surfaces and right angles because it allows the user to make a mapping with few cuts and minimal distortion (Fig. 19).



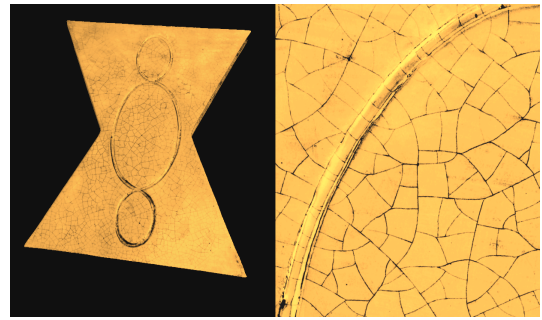
**Figure 19:** Left: Unwrap with the Smart Project method in Blender; right: final texture with gold color layer overlay.

All the softwares mentioned above allow for different methods to project textures on the surface, but they are usually not automatic and require experienced users. With the *SmartUV project* mode, the *unwrap* operation produces the mapping on the UV plane of the surface of the mesh (Fig. 19), which can be saved as an image with the desired resolution, i.e. 8192x8192 pixels in our case.

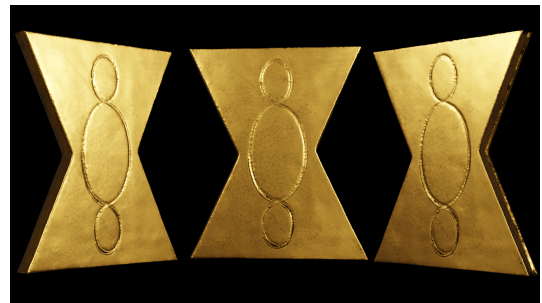
Using image processing software such as GIMP [GIM] or Photoshop [Pho], the obtained image can then be used as a basis for the final colouring of the mesh by superimposing on the map the corresponding parts obtained from the photographs of the artwork properly processed (Fig. 20). For this case study, we adopted Photoshop to edit images and produce the final texture. The top, bottom and lateral surfaces have been separately edited as follows. Firstly the RGB image has been transformed into a grayscale image, and brightness and contrast have been adjusted setting automatic levels. In case of local areas of strong shadow or highlight, the problematic regions have been replaced by patches from other images of the same object side, if available. This operation required some manual transform of the patch due to different camera orientation in the different images and was performed with high care in maintaining the correct *craquelé* pattern as much as possible. Then, we adjusted the small scale shadows/highlights using the *burn* tool and the *dodge* tool with zero % hardness to slightly darken/lighten small details. After the editing, we added each piece as a new layer on top of the unwrap image.

Using visual correspondence, we positioned the textured pieces over the unwrap layer; then we discarded the unwrap and merged all the layers. To obtain the final rendering, we added a top layer filled with an appropriate "gold" colour, i.e., RGB = (255,174,65), and merge it with the underneath grayscale texture in "multiply" mode.

Finally, the completion of the pipeline is achieved by assigning the physical characteristics to be reproduced (roughness, metallic, etc.) to the 3D model (Fig. 21). The material of the artwork affects not only the texture, but also its material consistency and how lights interact with the object, determining the final rendering. In Blender, physical-based materials can be created using shaders: Principled Hair, Principled Volume, and Principled BSDF. We used the Principled BSDF (Bidirectional Scattering Distribution Function) shader, which offers extensive possibilities to define how light is reflected and refracted on a surface and is suitable



**Figure 20:** 3D model colouring by texture mapping



**Figure 21:** Rendering of the final model

for metal surfaces. Many parameters may be configured, including *metallic*, *roughness*, *normal*, whose modulation allowed us to give the 3D model the reflectivity and refractivity properties best simulating the physical properties of the real artifact.

## 5. Conclusions

In this paper, we have described our digitisation experience on the case study of "The Golden Book of the Third Paradise", a contemporary ceramic artwork exposed at the Savona Ceramics Museum in Italy. The digitisation was a necessary step within a wider project for the design of an engaging experience around this piece of art using advanced interactive technologies [RBB\*20] [INT]. The artefact is particularly problematic. Firstly, it is coated with gold and therefore highly reflective. In addition, the object has a simple shape and highly symmetrical; however, it possesses features (en-graving of the "Third Paradise" symbol, pierces on the book due to the manufacturing process) and undercuts (book edges). This raises two issues: the symmetrical nature of the object can mislead the alignment of the image, and the noise in the data resulted to be of the same magnitude as the features.

Given the difficulties encountered during the acquisition and reconstruction process and the load of manual work, we could have opted for modelling the object instead. However, the artwork was stored in the museum and cannot be accessed freely; being precious and fragile, it could be handled only by the restorer and, consequently, a precise measurement of all the components and the features was not possible (the object is not perfectly symmetric).

Since the main goal was a high-quality and accurate digital

replica of the artifact, we performed the digitisation by photogrammetry, trying to keep the process as simple as possible and using freely available software. We experimented with different settings for capturing the photographs in order to optimise both the reconstruction of the geometry and the definition of the textures. Regarding the latter aspect, we found beneficial taking photos as perpendicular as possible, and capturing only portions of the surface to minimise the self-reflections. Regarding the first aspect, we strongly relied on markers and opted for acquiring the object on both sides to get a sufficient coverage of the whole artifact. Finally, we tested different tools and parameters in the various processing stages in order to obtain a geometrically and topologically correct model, as realistic as possible in terms of appearance.

Unfortunately, although the use of cameras is easier and affordable for less experienced users, the process to get a good quality result is still strongly manual and requires a sufficient competence in 3D modelling and processing; moreover, different software tools, even if free, are needed for the various operations. This is definitely a barrier to massive digitisation, especially for small museums, which have limited funds and staff to devote.

In the INTER-CH project, we have recently developed an interactive application based on a multi-touch table, which focuses on the artistic symbol of the Third Paradise and its 2D geometrical interpretation [RBB\*20]. The reconstruction of the 3D model of "The Golden Book" represents a further step towards the enhancement of a more immersive experience of the artwork. The next steps will focus on the inclusion of the third dimension in the current application, coupling the smart table with either screens or head mounted displays for augmented reality, or viewers for virtual reality. In this way, the visitor will be able to appreciate "The Golden Book of the Third Paradise" in a 3D environment, exploring it from various points of view and inspecting it in its details, with the addition of an entertaining storytelling.

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