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## REVERSE MODELLING PROCESS TO SUPPORT OF A FLEMISH WOODEN ALTARPIECE PHYSICAL RESTORATION

This study focuses on digital Computer Aided Restoration procedures to guide the complex physical restoration of an artwork, innovating and implementing traditional survey methods. As a case study some results are presented of a complex and articulated conservative restoration project on a sculpted and painted wing altar, preserved in the Regional Gallery of Sicily in *Palazzo Abatellis*, Palermo. The application of non-invasive and high information density 3D survey methodologies allowed to record and integrate into a unique digital platform (designed within the *UnReal Engine*) a wide quantity of heterogeneous data which document the work's state (diagnostic analyses, graphical annotation, historical information). The multidisciplinary investigation process is aimed to guide the disassembly of the various components, to tell the long process of activity in the laboratory and to experiment the realization and integration of

missing parts. The innovative application of 3D digital technologies shows how the integrated use of the new technology can be a useful tool for improving the conservation of a work of art. The data processed have permitted a better interpretative reading, implementing the knowledge of the scholars, and a more effective communication and fruition to the audience.



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## 1. INTRODUCTION

In the field of dissemination and preservation of Cultural Heritage (CH), the digital technology introduces new synergies and effective procedures for data acquisition, processing and storage. In this direction, museums, art galleries, archives, superintendence and organizations specialized in the preservation, diagnostics and restoration of works of art and archaeological finds are investing more and more in the design of digitization processes to promote their collections of works of art improving the conditions of use by users (Apollonio et al., 2018; Arbace et al., 2013; Marraffa et al., 2021). The *Smithsonian X3D* project (the *Smithsonian Museums* in collaboration with *Autodesk*) is a significant example of best practices in the field of CH. This project aims to digitize all the heritage of the Institute, creating a database accessible to scholars and visitors and allowing to obtain a heterogeneous integrated documentation that can be shared and implemented over time.

Activities that employ digital preservation technologies for art assets lead to the creation of a digital product using integrated non-invasive photogrammetry and 3D scanning techniques to enhance the scientific analysis tools for a better knowledge and understanding (Grilli et al. 2018; Inzerillo, 2019). Moreover, from discussions with colleagues in the conservation field, it was deemed important to define effective support procedures to implement and refine the analysis, data querying and control of the geometric digital model, to provide useful evaluation support before, during and after restoration interventions.

Even today, in the field of CH conservation, expert restorers initiate conservation projects relying exclusively on 2D technical drawing and thematic maps associated with textual legends (e.g. 2D GIS systems, such as *SICAR*, widely used in activities coordinated by *MIBACT*, or the 2D computer drawing systems recently used by *ICR* to map the state of conservation of the Colosseum). Based on the 2D metric data collected, the subsequent restoration phases of the damaged areas are started. Intervention strategies defined based on collected

2D data are often unreliable and subjective, especially when the case study surface is geometrically complex (Di Paola et al., 2017).

This study is within this context and describes the workflow for the acquisition and creation of a digital model using non-invasive hardware techniques and high information density digitization software to assist the conservation of a valuable 16th Century wooden Altarpiece that is on exhibit at Palazzo *Abatellis* in Palermo.

With the intention to propose new solutions for analysis and documentation, the study presents the evaluation of a methodology that allows to implement and optimize acquired digital data, suitable for different purposes related to conservation restoration and museum fruition (Lo Turco et al., 2019). The presented investigation process aims to obtain a complex and semantic 3D model with high information density, navigable and labelled with the ability to annotate heterogeneous informa-

tion (Attene et al., 2007; Echavarria et al., 2012). Moreover, an algorithm written in *Python*, within the *Blender* environment, is presented, which implements the creation of 3D regions directly on the polygonal mesh with the texture applied according to semantic criteria established by the project (e.g. selected by type of degradation, by construction technique, by material differentiation) (Gonizzi et al., 2017; Abergel et al., 2021).

## 2. CASE STUDY

The winged altarpiece in carved, gilded and painted wood that is the subject of this study, belongs to the collection of the Sicily Regional Gallery, Palazzo *Abatellis*. It was part of the corpus of the Benedictine Museum of the Abbey of San Martino delle Scale, Palermo. The artifact was probably purchased in Italy before 1773 by

Fig. 1 - Altarpiece with closed wings before and after restoration, Sicily Regional Gallery, Palazzo *Abatellis*



Fig. 2 - Altarpiece with open wings before and after restoration, Sicily Regional Gallery, Palazzo Abatellis.



the Monastery's abbot Salvatore Maria Di Blasi, who in that date already mentioned it among the artworks present in the Museum. The Altarpiece is composed of a wooden case, shaped like an inverted "T" (dimension box: L 170 cm; W 20 cm; H 166,5 cm), with a hinged structure that expands the decorative surface of the artifact and allows a double reading. When the Altarpiece is closed, the visible iconographic themes are that of the "Annunciation" at the top, the "Virgin and Child" and "St. Catherine of Alexandria" in the main panels. When the panels are open, however, the surfaces are doubled: the flat surfaces of the wings, where a "Virgin at the loom" and a "Virgin reading" are represented at the top and, at the bottom, "Joseph's choice" and the "Adoration of the Magi", are contrasted by a dense sculptural structure: in the center is a "Nativity" and at the sides, the "Marriage of the Virgin" and the "Circumcision", respectively on the left and right.

An elaborate gilded architectural backdrop in the Gothic style acts as a canopy for the three groups. This is composed of loggias of mullioned windows, balustrades, pinnacles, pointed arches supported by tall columns with phytomorphic capitals. The architecture of the central area housed four statuettes, now lost, surmounted by canopies. At the center of the composition was the "Eternal Father" flanked by two angels, now lost. Considering that the position of the Altarpiece inside the churches was elevated with respect to the normal point of view, the entire composition presents a perspective view designed to be observed from below (fig. 1, 2).

### 2.1. ARTWORK STYLISTIC DESCRIPTION

From a stylistic point of view, the work is unique in the Sicilian Patrimony, since it can be assimilated to the production of winged altarpieces with sculptures, of the Netherlands of the late 15th Century and, in particular, to that of the centers of Antwerp and Brussels, active between 1380 and 1550. This production was characterized by a type of serial and standardized workmanship that allowed the

creation of large-scale artifacts in short time, intended for the free market, where the buyer was less demanding than the patrons who required customized works. The artifacts were offered ready-made and marketed both within the same workshop of production, as well as in fairs or art markets such as the *Onser Liever Vrouwen*, adjacent to the church of Our Lady in Antwerp, 1480. Another interesting comparison, that confirms the belonging of our Altarpiece to the barbante production, can be made with the Altarpiece of the "Nativity" coming from the Monastery of the Clarisse of St-Josefsberg to Megen, today preserved to the Bode Museum of Berlin, of unknown authors of Brussels, dated 1470-80 [1] (Abbate, 2012). Both the exemplary ones introduce obvious correspondences with our example in the executive technique, in the style of the architectures and in the iconographic lines, so much of the sculptures, how much of the paintings, so to be able to bring them back to the same period and center of production (fig. 3).

## 2.2. THE EXECUTIVE TECHNIQUE

Some documents of the mid-15th Century, relating to the craft guilds of Brussels, show how the realization of the altarpieces, was entrusted to the collaboration of different workers, each of which was dedicated to a specific construction phase: the carpenters made the cases, the sculptors the plastic part then finished by decorators and painters. The case consists of a bottom made of six oak planks with crossbars and eight perimeter planks that define the thickness, connected together by dovetail joints. The panels are bound to the perimeter of the case by iron hinges. A small iron lock, with the typical hemmed motif of Flemish palaces, allowed the closing of the altarpiece. The surfaces of the entire artifact are gilded with different construction techniques. A particular decorative technique, found on the draperies of some figures and on the drapes that are the background of the "Madonna and Saint Catherine", is that of the "broccato applicato". The sculptural groups and the architectural elements are bound to the back wall by means of iron nails, hammered in from the back.



Fig. 3 - Altarpiece of the "Nativity of Medgen", collection of the Bode Museum, Berlin inv. 8077 ([https://commons.wikimedia.org/wiki/File:Winged\\_altarpiece.jpg](https://commons.wikimedia.org/wiki/File:Winged_altarpiece.jpg)).

## 3. MATERIAL AND METHODS

Within the Gallery's Restoration Laboratory, the integrated application of digital procedures has allowed to guide the process of artefact conservation, innovating and implementing traditional methods of investigation. The skills of the multi-disciplinary team, composed of restorers from the Gallery and researchers from the Department of Architecture of the University of Palermo, were fundamental for the restoration and virtual anastylosis. The restoration has been supported by a series of cognitive investigations that have allowed to study the artifact, identifying the materials used, the executive technique and its state of preservation, following the theoretical criteria of minimum intervention, recognizability, compatibility and reversibility, adopting conservative strategies in respect of the work and its history. [2]

The diagnostic investigations, visual analysis and surveys conducted on the artifact in the preliminary phase of the intervention, showed a pronounced state of degradation. The structure of the case presented disconnections of the axes to be attributed to the lack of one of the crossbeams, the sculptural groups were lacunose and lacking in some elements as well as the architectures. The survey started required the planning of a complex campaign to support the diagnostic investigations and the material and structural conservation. The artwork has been scrupulously disassembled in every part by the restorers and this logistical aspect has been a great advantage because it has allowed an easier digital acquisition to realize a 3D semantic model (figg. 4,5).

In the final phases of the restoration, it was also possible to reconstruct the sequence of assembly of the various parts, supported by the navigation



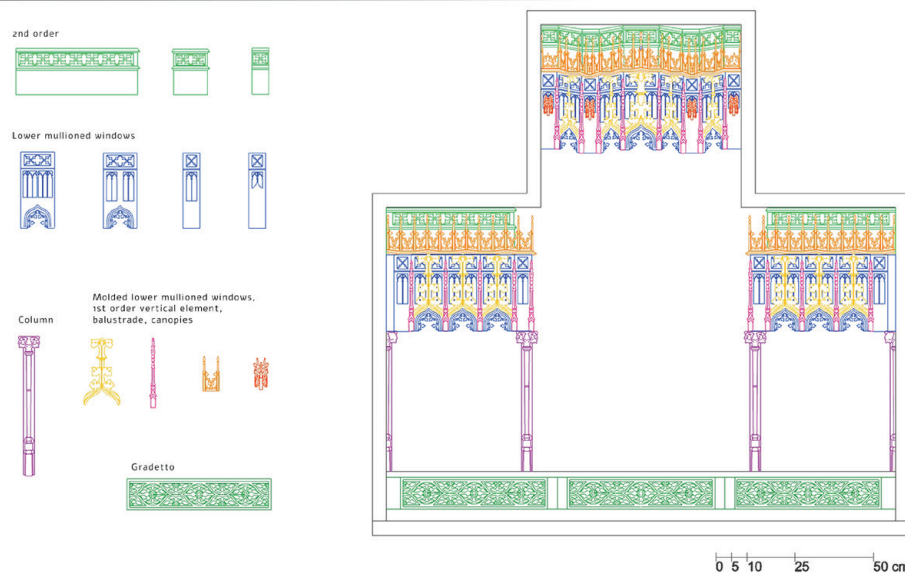
Fig. 4 - Artwork details during the restoration. Altarpiece, Sicily Regional Gallery, Palazzo Abatellis.

and interrogation of the semantic 3D model created. A shared design choice was not to physically reconstruct the modular elements of the retable, but to reproduce them thanks to the 3D survey campaign. Therefore, the disciplinary contribution has been fundamental, since it has been possible to start hypothesis of restoration and virtual analysis of the compositive apparatus of the artefact, so as to allow the user to perceive the artwork in its complexity. The 3D model, digital copy of the original artwork, has been a very valuable tool in the procedural workflow and has allowed to plan and develop strategic actions to be taken to activate virtuous processes of preservation and enhancement, some still in progress (storytelling paths, archiving or interrogations and implementations with subsequent diagnostic investigations, *gaming*, scale reproductions with rapid prototyping technique, interactions in virtual visualization).

### 3.1. 3D SURVEY PROJECT

The reverse modelling acquisition process required programming activities over 1 month, collecting 50 geo-referenced scans, which were subsequently processed. The choice of instrumentation was determined by the heterogeneous features of the artwork under study. Integrated techniques were used to overcome the many difficulties related to the capture conditions (reflective surfaces, undercuts, multi-scale components, logistical difficulties of access and handling). The process of reverse modelling with 3D scanning acquisition technique took place without direct contact with the artwork, through the mediation of optical, mechanical and ITC tools that restored the artwork representation in the form of a three-dimensional model (Andriasyan et al., 2020). Since the artwork has an articulated geometric structure of variable dimensions and decorative apparatus with small details, it was necessary

Fig. 5 - Modular elements of retable architectures. Altarpiece, Sicily Regional Gallery, Palazzo Abatellis.



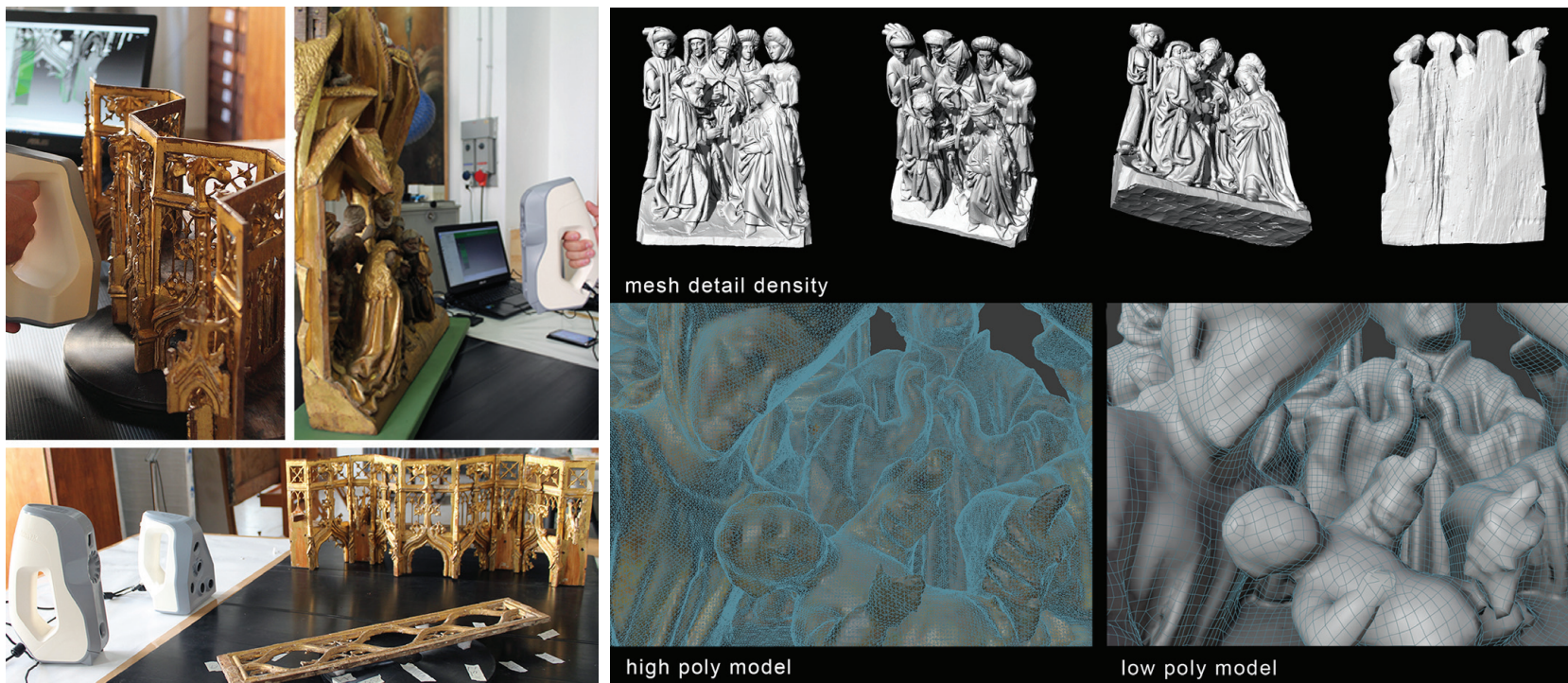


Fig. 6 - The survey campaign in Laboratory, Sicily Regional Gallery, Palazzo Abatellis.

Fig. 7 - Altarpiece 3D digital models, Sicily Regional Gallery, Palazzo Abatellis. Above, polygonal mesh of the sculptural group the "Marriage of the Virgin"; below, polygonal load management of the sculptural group the "Circumcision".

to have an integrated surveying instrumentation able to maintain a high density of information. Therefore, thanks to the collaboration with the Department of Civil Engineering of the University of Salerno, it was possible to combine the data acquired by two structured light instruments of the same manufacturer (the *Artec* instruments, the *Spider* and the *Eva*). The well-known portable and extremely versatile point cloud acquisition systems do not necessarily require the presence of markers in the scene and, thanks to the presence of a structured light LED bulb, overcome the interference of any adverse lighting conditions of the surrounding environment (fig. 6). [3]

The coordinates of the point cloud belonging to the different scans acquired have been geo-referenced in the same reference system, determining a single CAD model. The procedural steps of alignment, registration and texturing were carried out with the dedicated software *Artec Studio*. The first procedural steps of post-processing and tessellation of the polygonal mesh have been elaborated within the *Leios* reverse engineering software (*EGS* company). Considering the geometry of the surface (curvature, contiguity edges and density of the polygonal mesh) the spatial structure of the model undergoes corrections, removing some artefacts generated by the scanning process. But

further control will be needed to optimize the geometry and eliminate topological errors (fig. 7).

#### 4. RESULTS

Particular attention has been paid to the control of the polygonal density of the surfaces with the aim of not losing the quality of information of the detail, but at the same time, to ensure easy management on a dedicated digital platform, to accompany the digitized version of the Altarpiece with notes, historical information, data relating to specific measurements, comments of scholars

and experts. In this direction, the methodology employed defines a path aimed at determining high quality 3D mesh digital models with associated textures, suitable for effective consultation during conservation restoration phases.

The procedure follows a reasoned path that elaborates the topological structure of the geometric model, analysing and resolving calculation and colour errors, reorganizing the collected data according to criteria defined in synergy with the expert restorers (Niang et al., 2017).

The pipeline described below may be applied to several commercially available software. We have preferred to develop the process in within the *Blender* work environment (stable version 2.93 and beta version 3.0). The main steps of the methodology performed are described below (fig. 8).

#### 4.1. PROJECT ISLAND AND UV MAP LAYOUT OPTIMIZATION

The process of mesh management and texture mapping consists of the following steps: mesh parameterization, mesh partitioning, mesh segmentation unwraps, UV map and island projection, UV layout optimization, mesh packing and baking. Before proceeding to the mesh segmentation, it's necessary to check for topological errors to optimize the mesh structure. Following the phases of the set method, for each of the acquired 3D models the following steps have been developed: Removing Doubles Vertices from the acquired Mesh and closing seam, and edges connections review. After, depending on the future visualization mode of the models it is necessary to determine which polygonal load to assign to the resulting surface. According to the field of application (restoration and conservation studies or real-time visualization for museum use), we choose the path to follow continuing to work on a model with full polygonal load or on a lighter one for a real-time display. These steps allow to optimize the polygonal weight of the object compared to the initial acquired mesh, dividing the geometry in a custom way. Since the models will be able to be viewed on web dissemination platforms, re-meshing and retopology processes have been initiated on the polygonal

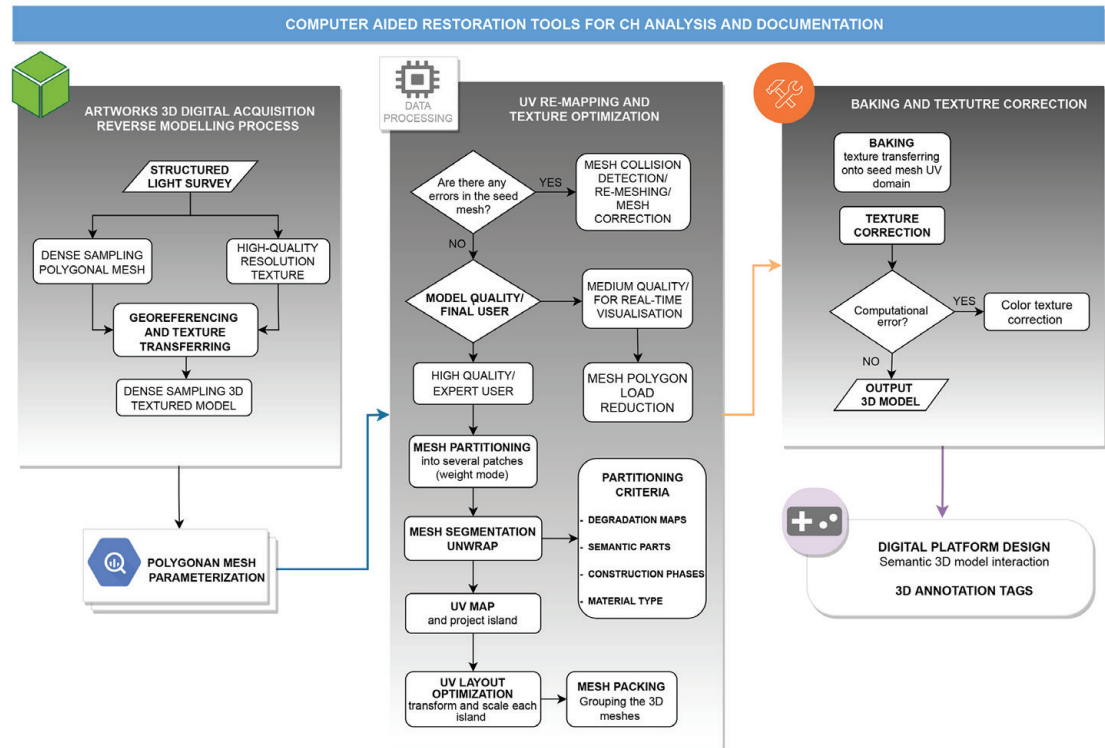


Fig. 8 - The flowchart shows a procedure to optimize, analyse, control and visualize the scanned 3D models.

model. The algorithm replaces the original mesh with a new one that preserves certain formal characteristics (vertex position and edge geometry). The mesh reconstructed with a reduced number of polygonal faces (low poly) must maintain the shape of the original mesh (high poly). The UV mapping method correlates the spatial coordinates of the polygon mesh (related to the points and mesh vertices) to texture coordinates; the *Artec Studio* software uses the "atlas texture" method (resolution texture used: 4096 x 4096). An atlas texture is a large image containing a collection, or "atlas," of sub-images, each of which is a texture for some part of a 3D object. This method cuts the

surface into chunks, unfolds, and nests them flat, and fits them into the image of a specified size. From literature and experience we know that in the texture mapping phase the most common problems are: low texture resolution; missing colour in some mesh portions and photo inconsistencies and topological errors due to formal geometric complexity. So, the level of colour quality obtained with the scanner is not acceptable for mapping high quality colour textures. Therefore, a rigorous methodological process was defined with the goal of optimizing the starting textures. The Texture mapping method used includes multiple processing, such as mesh partitioning, mesh parameterization,

texture transferring, and correction and optimization, which are related to each other and affect the texture quality (Lai et al., 2018).

The latest software technology uses dedicated tools for generating UV vertex maps to assign texture to a numerical model with a complex geometric shape. Since the texture is a planar 2D figure, UV vertex maps establish a two-way correspondence between the vertices of the 3D polygon mesh and the pixels in the image. The libraries available within the *Blender* software use an automatic procedure for creating UV Maps. The tool is called *Smart UV Project*.

If we choose this option *Blender* will try to automatically place new seams and unwrap the mesh, but, often, the result is not adequate because it does not allow the geometric-formal features of an object and other custom user-defined aspects. Therefore, we have started to develop alternative methods to create a mesh unwrap that is more compatible with its geometry and other custom user-defined aspects. The purpose is to segment the resulting meshes into patches and unwrap them onto a 2D planar surface, according to semantic criteria imposed by the user. Next, the defined tool is described.

#### 4.2. 3D TOOLS FOR CH DOCUMENTATION

After acquiring the digital models, the aim of the study is to allow the visualization and geometric analysis of the model with the possibility to create 3D regions directly on the polygonal surface. Managing a mesh surface of a complex 3D model and selecting individual regions for subsequent annotation is not an easy task. The tools available in current software do not guarantee total control of the mesh structure (Ponchio et al., 2020; Savini et al., 2021). In this direction, therefore, the goal concerns the creation of a semantic segmentation for parts of the mesh acquired (unwrap phase) according to criteria imposed by the user (in relation to the geometric morphology or special needs relating to time dating, degradation, materials, construction techniques, etc.). To implement the control and analysis tools, we propose alternative methods defined by algorithms, a raster approach written in *Python*.

Fig. 9 - Selection and extraction areas directly on the polygonal mesh surface, using the colour variation. *Python* Implementation

Specifically, in *Blender*, using the “Texture Painting” mode, you can select the geometry with the texture applied with the “Clone Stamp” tool. There are two methods to use this tool: in manual mode and in automatic one. In automatic mode, with the aim to achieve a semantic and automatic selection of the polygonal mesh, the study presents an implementation of this tool. In the *Blender* environment we used *Python* to define an algorithm capable of selecting and extrapolating areas directly on the polygonal mesh surface, using the colour variation. This alternative method creates a mesh unwrap that is more compatible with the geometric-formal features of a complex object and/or with other custom user-defined semantic criteria, relative to the degradation maps of the restoration project. Experimentally, the selection procedure was applied to the central sculptural group “Nativity”, reproducing in 3D the design mock-up of the 2D degradation maps of the restorers’ colleagues (fig. 10). The specific addon is described in detail below.

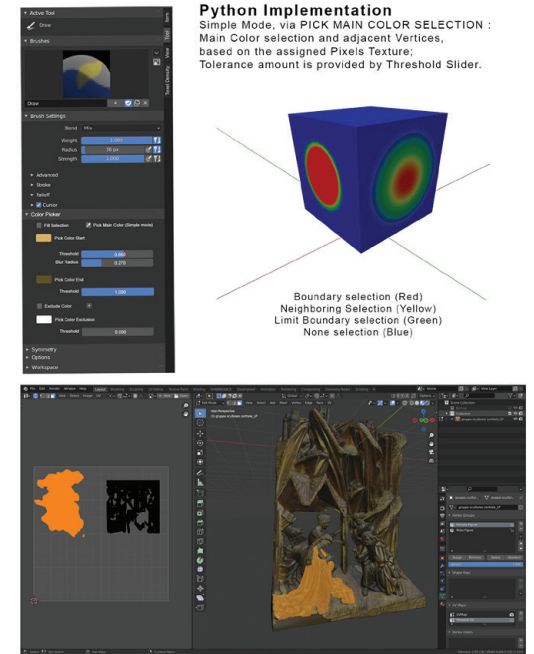


Fig. 10 - Model unwrap meshes concerning restoration project degradation maps (execution techniques and state of conservation).





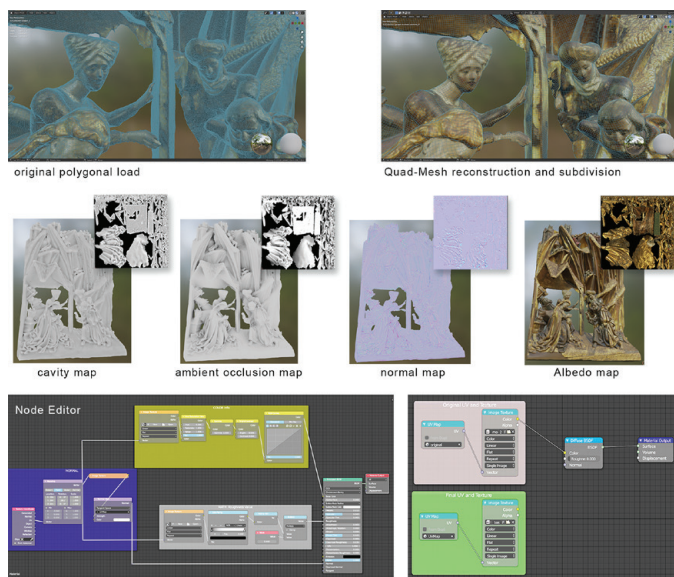


Fig. 11 - Optimization process of polygonal load and baking, from the "original" UV-Map to the final one with the assigned baking image.

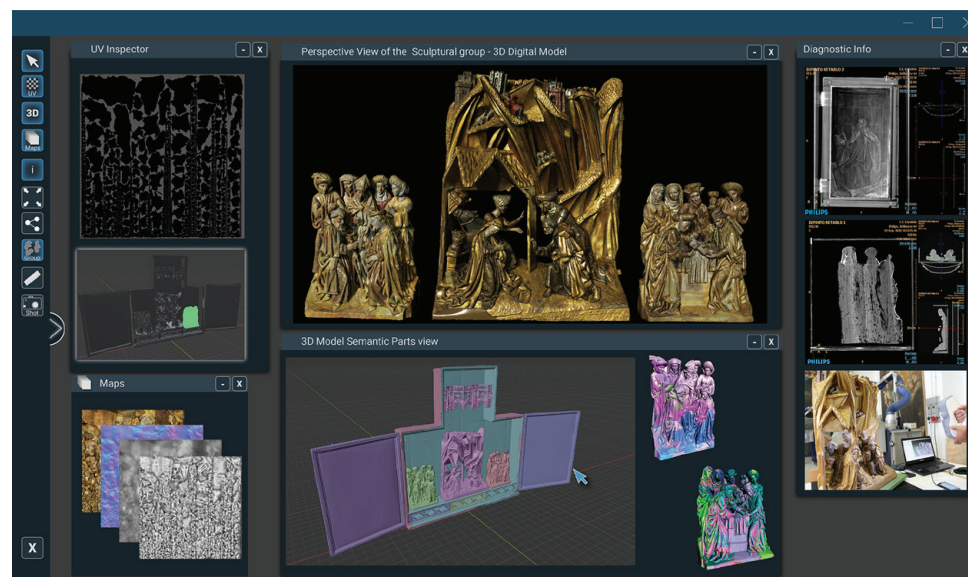


Fig. 12 - Browse the digital platform in "expert user" mode. Annotations and infographics linked to the 3D digital model via tags.

The weight is translated into shades of colour using red, yellow, green and blue. Each colour has a specific meaning.

- The *Red* colour is decoded by the tool as a user defined selection and represents the boundary selection.
- The *Yellow* colour is decoded by the tool as an extension or expansion selection. This happens after having selected and chosen inside the box colour "pick colour start" the selection colour tonality.
- The *Green* colour identifies the end of the selection that is chosen by the box colour "pick colour end", the slider threshold manages the visibility as well as the extension.
- The *Blue* colour indicates that no selection (or exclusion) of pixels and, consequently, of mesh vertices has been made.

The algorithm has been defined according to the simple mode of automatic interaction via "pick

main colour selection". This mode selects a main colour and automatically also the adjacent vertices corresponding to the pixels of the texture assigned to the object (fig. 9).

The Colour picker modes are two: "Pick Colour Start" Function (Pick the vertex with the primary colour assigned to it) and "Pick Colour End" function (Pick the vertex with the primary colour assigned at the end of the selection). The parameter that manages the "Pick function" and the selection tolerance is the "Threshold" slider, while the "Blur Radius" function manages the selection blur. Modifying the "Threshold" and "Blur Radius" parameters the extension changes on the adjacent similar pixels, and therefore, parametrically the vertices below. Finally, "Exclude Colour" and "Pick Colour Exclusion" function have the role to select the vertexes with assigned the "external" colour to the selection criterion. It applies if within the selection area the vertices with different colours are automatically selected.

#### 4.3. BAKING AND TEXTURE CORRECTION

The Baking procedure defines a UV vertex map and it collect the data of the high polygonal load model, and "cook" them in a low polygonal load model. [4] To proceed with the baking procedure, it is necessary to create a material within the "Node Editor" of *Blender* and assign new procedural textures to the resulting mesh. These procedural textures are specially created to store information in 2D maps without adding geometry to the model, such as the Displacement map, the Lightmap, the Cavity map, etc. The textures have been reproduced in procedural mode, displaying shaders using a graph pattern.

In the final step of texture optimization, after baking, some areas of interest have been selected with the Texture Painting mode tool and emphasized (by creating masks) editing some parameters such as: saturation, contrast and brightness. Following this process of editing and

optimizing the texture applied, each model is assigned: the initial mesh with original *UV-Map Arrangement*, the *Matcap Visualization* with final *UV-Map Arrangement* and the final mesh, with the final baked UV-Map disposition. The result is a very dense sampling of both geometric and texture surface properties of real objects and the quality of the entire 3D textured model can therefore be improved for the purpose of CH dissemination (fig. 11).

#### 4.4. DEDICATED DIGITAL PLATFORM DESIGN

In the field of CH conservation, the so-called “serious games” have proved to be an effective tool and resource for the dissemination, especially for the new generations, in a single interactive and integrated digital context, present the historical-cultural and technological specifications of a work of art. The implementation of the platform and the procedural applications can generate interesting keys to reading for different types of interlocutors (Parrinello et al., 2017; Serna et al., 2012).

The designed interface, within the *UnReal Engine* environment (by *Epic Games*), allows navigation in two interaction modes. The first one allows the 3D model geo-referencing with 2D infographics and documentation (images, archive photos, schemes and drawings), through reference tags. The second mode allows the user to immerse himself in a realistic scenario and to navigate the 3D model in game mode (Yu et al., 2013).

In the “Expert User” mode (fig. 12), the scholar can query the semantic model, visualize and inspect the model with the mapping of the applied materials. In the “UV inspector” section, it is possible to select the areas of interest in the 3D scene and at the same time there is a visualization in two-dimensional space of the arrangement of the “islands” within a 2D space. Of particular importance are also the windows related to the diagnostic information that are displayed by selecting with appropriate tags the areas of the model. Finally, the interface allows to load the window related to the maps applied to the 3D model, which illustrate the elaboration process applied. In the second mode “Museum User”, instead, the user has full

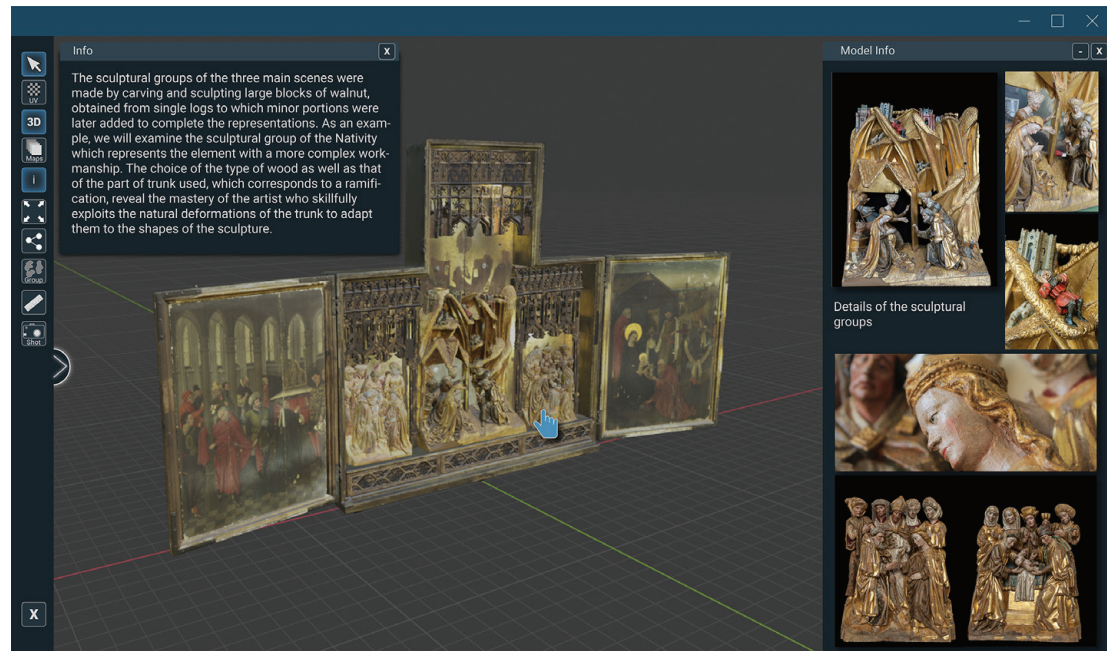


Fig. 13 - Browse the digital platform in “museum user” mode. Semantic 3D model interaction.

freedom of movement and can completely immerse himself within a 3D space that allows him to interact with the analysed object, rotating and translating its individual components. The user’s experience is also enriched by some specific images of the case study model, with annexed historical and technical information (fig. 13).

## 5. CONCLUSIONS

The aim of the study was to provide effective geometric-formal survey tools to support traditional intervention methods and techniques. The application of innovative non-invasive and highly informative 3D integrated survey methodologies allowed to record a large amount of data, documenting the state of the work, and to experiment

the realization and virtual integration of some missing retablo components.

The graphical representation of the semantic model has been configured as an important tool to support the restoration. It has been possible to document with geometric rigor directly on the 3D model the mapping of the damage, the executive techniques and the restoration interventions on all modelled surfaces. The interrogation of the model and the possibility to isolate the various components by observing them from different points of view makes it an effective tool also in terms of valorisation, especially if accessible from remote.

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## APPENDIX

Author Contributions: All authors conceived and designed the experimental campaign; all authors wrote the introduction, and the conclusions; G.D.M. performed and wrote "Artwork stylistic description" and "The executive technique"; F.D.P. performed and wrote the "Material and Methods" and F.D.P. and Y.A. performed and wrote the "Results".

NOTE

[1] *Nativity Altarpiece from Medgen, 1470-80 ca.*, Bode Museum, Inv. 8077.

[2] Direction of the works dr. Evelina De Castro; planning and restoration intervention by the restorers of the Laboratory of Palazzo Abatellis: Rosario Barreca, Arabella Bombace, Concetta Greco; restoration of the structure of the carpentry Laboratory of the Museum: Enzo La Porta, Antonino Sciortino; restoration of wooden panels and reassembly by restorer Gianfranco Di Miceli. Collaboration on restoration work: restorer Stefania Caramanna. Diagnostic investigations: Ing. Bartolomeo Megna, Dott. Giuseppe Salerno, S.T.ArtTest.

[3] The Artec instruments, the Spider and the Eva, are equipped with camera sensors with different depth angles and a projector capable of emitting frames per second (8 or 16 respectively, automatically aligned in real time), capturing up to 1,000,000 points per second within a set range of action. Reflected images of the surface are captured by the cameras, and from pattern distortion analysis, the position of the dot array is constructed. The scanning devices also capture textures (1.3 Mp texture resolution and 24 bpp image colour).

[4] For instance, these data are morphological data (onerous calculation of the simulation of the light/ *global illumination, radiosity*), *normal maps* of the RGB type, *displacement maps*

REFERENCES

Abbate, G. (2012). *Pittura e scultura lignea fiamminga della prima metà Cinquecento in un inedito altare a battenti dai depositi della Galleria di Palazzo Abatellis*, conference brochure, Galleria Regionale della Sicilia di Palazzo Abatellis, Palermo.

Abergel, V., Jacquot, K., De Luca, L., Veron, P. (2021). Combining on-site and off-site analysis: towards a new paradigm for cultural heritage surveys. *Disegnarecon - Semantic-driven analysis and classification in architectural heritage*, 14(26), <https://doi.org/10.20365/disegnarecon.26.2021.13>.

Andriasyan, M., Moyano, J., Nieto-Julián, E., Antón, D., Remondino, F. (2020). From Point Cloud Data to Building Information Modelling: An Automatic Parametric Workflow for Heritage. *Remote Sens MDPI*, 12(7), <https://doi.org/10.3390/rs12071094>.

Apollonio, F. I., Basiliusi, V., Callieri, M., Dellepiane, M., Gaiani, M., Ponchio, F., Rizzo, F., Rubino, A. R., Scopigno, R., & Sobra', G. (2018). A 3D-centered information system for the documentation of a complex restoration intervention. *Journal of Cultural Heritage*, 29, 89-99, <https://doi.org/10.1016/j.culher.2017.07.010>.

Arbace, L., Sonnino, E., Callieri, M., Dellepiane, M., Fabbri, M., Idelson, A.I. and Scopigno, R. (2013). Innovative uses of 3D digital technologies to assist the restoration of a fragmented terracotta statue. *Journal of Cultural Heritage*, 14(4), 332-345, <https://doi.org/10.1016/j.culher.2012.06.008>.

Attene M., Robbiano F., Spagnuolo M., Falcidieno B. (2007). Se-

mantic annotation of 3D surface meshes based on feature characterization. *Semantic Multimedia, Second International Conference on Semantic and Digital Media Technologies, SAMT*, Springer LNCS 4816, 126-139, [https://doi.org/10.1007/978-3-540-77051-0\\_15](https://doi.org/10.1007/978-3-540-77051-0_15).

Di Paola, F., Milazzo, G., & Spatafora, F. (2017). Computer aided restoration tools to assist the conservation of an ancient sculpture. the colossal Statue of Zeus enthroned. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, CIPA, (XLII XLII 2/W5, pp. 177-184), Copernicus Publ. <https://doi.org/10.5194/isprs-archives-XLII-2-W5-177-2017>.

Echavarria K.R., Theodoridou M., Georgis C., Arnold D., Doerr M., Stork A., Serna S.P. (2012). Semantically rich 3D documentation for the preservation of tangible heritage. *VAST: International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage*. Arnold D., Kaminski J., Niccolucci F., Stork A., (Eds.), The Eurographics Association, <https://doi.org/10.2312/VAST/VAST12/041-048>.

Grilli, E., Dinunno, D., Petrucci, G., and Remondino, F.: From 2d to 3d Supervised Segmentation and Classification for Cultural Heritage Applications, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2, 399-406, <https://doi.org/10.5194/isprs-archives-XLII-2-399-2018>, 2018.

Gonizzi Barsanti, S., Guidi, G., and De Luca, L.: Segmentation of 3d Models for Cultural Heritage Structural Analysis – Some Critical Issues, *ISPRS Ann. Photogramm. Remote Sens. Spatial Inf.*

*Sci.*, IV-2/W2, 115-122, <https://doi.org/10.5194/isprs-annals-IV-2-W2-115-2017>, 2017.

Inzerillo, L., Di Paola, F., Alogna, Y. (2019). High Quality Texture Mapping Process Aimed at the Optimization Of 3D Structured Light Models. 3D Virtual Reconstruction and Visualization of Complex Architectures. *Int. Arch. Photogramm. Remote Sens. Spatial Inf.*, vol. XLII XLII 2/W9, p. 389-396, Editor(s): A. Cardaci, F. Fassi, and F. Remondino, Bergamo, <https://doi.org/10.5194/isprs-archives-XLII-2-W9-389-2019>.

Lai, J.Y., Wu, T. C., Phothong, W., Wang, D.W., Liao, C.Y., & Lee, J.Y. (2018). A High-Resolution Texture Mapping Technique for 3D Textured Model. *Applied Sciences*, 8(11).

Lo Turco, M., Calvano, M., and Giovannini, E. C. (2019). Data modeling for Museum Collections, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-2/W9, 433-440, <https://doi.org/10.5194/isprs-archives-XLII-2-W9-433-2019>.

Marruffa, A., Fatta, F. (2021). The digital anastylosis and the semantic segmentation: the case of the Magna Graecia masks in the Mediterranean area. *Disegnarecon - Semantic-driven analysis and classification in architectural heritage*, 14(26), <https://doi.org/10.20365/disegnarecon.26.2021.12>.

Niang, C., Marinica, C., Markhoff, B., Leboucher, E., Malavergne, O., Boullier, L., Darrieumerlou, C., & Laissus, F. (2017). Supporting Semantic Interoperability in Conservation-Restoration Domain: The Parcours Project. *Journal on Computing and Cultural Heritage*, 10(3), 1 20, <https://doi.org/10.1145/3097571>.

Parrinello, S., Bercigli, M., & Bursich, D. (2017). From survey to 3D model and from 3d model to “videogame”. The virtual reconstruction of a Roman Camp in Masada, Israel. In *Disegnarecon - Archaeological drawing*, 10(19), 1-19, <http://disegnarecon.univaq.it/ojs/index.php/disegnarecon/article/view/295>.

Ponchio, F., Callieri, M., Dellepiane, M. and Scopigno, R. (2020). Effective Annotations Over 3D Models. *J-Global*, 39(1), 89-105, [https://jglobal.jst.go.jp/en/detail?JGLOBAL\\_ID=202002239260790108](https://jglobal.jst.go.jp/en/detail?JGLOBAL_ID=202002239260790108).

Savini, F., Fabbrocino, G., Marra, A. (2021). Digitization of Historical Architectural Elements, a workflow for Knowledge of Minor Centers in inner Areas, *Disegnarecon - Semantic-driven analysis and classification in architectural heritage*, 14(26), DOI: 10.20365/disegnarecon.26.2021.9.

Serna, S.P., Schmedt, H., Ritz, M., & Stork, A. (2012). Interactive Semantic Enrichment of 3D Cultural Heritage Collections. *VAST: International Symposium on Virtual Reality*, 33-40, <http://dx.doi.org/10.2312/VAST/VAST12/033-040>.

Yu, C.H., Hunter, J. (2013). Documenting and sharing comparative analyses of 3D digital museum artifacts through semantic web annotations. *Journal on Computing and Cultural Heritage*, 6(4), 1 20, <https://doi.org/10.1145/2532630.2532634>.