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Digital reconstruction and scientific analysis prior the restoration of two paintings by Mattia Preti in the *Church of the Immaculate Conception of Sarria* (Floriana, Malta)

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***Abstract* – The paper presents the results of scientific investigations carried out in support of a professionally executed restoration on two paintings by Mattia Preti, located in the *Church of the Immaculate Conception of Sarria* in Floriana, Malta. In particular, the attention was mainly paid on a combined approach, using 2D/3D survey in order to formulate hypothetic reconstruction, and XRF spectroscopy in order to get more information on how the master prepared the various types of materials, with particular regard to the painting preparation, the pigments palette and the formulation of shades and highlights.**

I. INTRODUCTION

Inside the city walls of Floriana, an eighteenth-century suburb of Valletta, capital of the Republic of Malta, there is the *Church of the Immaculate Conception of Sarria* (Fig. 1), whose current conformation is closely connected with the figure of the famous painter Mattia Preti. It is the only building surely designed by the "Calabrian Knight" between 1676 and 1677. The church [1] was commissioned as an *ex voto* to express the devotion to the Virgin and to the thaumaturgical saints *Sebastiano, Rocco, Rosalia and Nicola of Bari* invoked to intercede to eradicate the plague that caused thousands of deaths in Malta in 1676. Mattia Preti is also the author of the entire interior decoration, made up of seven paintings executed between 1677 and 1679. They are inspired by the seven frescoes that he had painted on the seven gates of the city walls of Naples, as *ex-voto* for the end of the plague epidemic of 1656 (as documented by two sketches kept at the Capodimonte Museum in Naples). The pictorial cycle of Sarria is completed with the two large Lunettes of the arches (Fig. 1), which represent examples of the struggle of Good against Evil in relation to the plague disease interpreted as divine punishment. The Lunette 1 (on the left) is dedicated to *Saint Michael defeating Evil*, while the one on the right (Lunette 2) represents the *Allegory of the Order of Saint John the Baptist* who, thanks to its dual military and hospital vocation, defeats evil.

Fig. 1. Location of the Lunette 1 and Lunette 2 within the Church of the Immaculate Conception of Sarria (Floriana, Malta). The inset shows the location of the church within the geographic context.

This paper presents the main results obtained by means of digital photogrammetry for the two paintings with the final goal of digitizing the two masterpieces and having a model to be used to plan and support the different restoration phases.
In addition, a preliminary diagnostic analysis by means of X-ray fluorescence (XRF) spectroscopy, was performed on both paintings, but in here we present some preliminary results obtained for the Lunette 1, as an example. The XRF investigation was aimed at achieving, through the evaluation of the elemental composition of the materials, information concerning the manufacturing technique, painting style and color palette used by Mattia Preti during the production of his artworks. Knowledge of these aspects represents a fundamental pre-requisite in view of the development of proper restoration strategies to be applied. Furthermore, the XRF elemental analysis could experimentally support hypothesis about the dating of the painting to the Maltese period of artist.

II. DATA ACQUISITION AND PROCESSING

Geomatic surveys offer unlimited possibilities of digitizing and studying both cultural heritage and environment. They have the great advantage of being a valid support at several scales [2-6]. In particular, photogrammetry, which is a relatively new technique, can be used to obtain reliable information about the spatial properties of the investigated objects, and it can be considered a useful tool for documenting and studying cultural heritage. It allows the development of 2D/3D digital objects that can be used to capture, share, visualize and annotate the studied artifact. The photogrammetric process technique consists of several phases of processing (see [3] for more details). The processing of the acquired images follows 5 main stages, summarized hereafter.

- *Image acquisition and selection:* Images were acquired through the use of a digital camera assuring a good amount of image overlapping. Preliminary processing was carried out in order to discard those of poor quality.

- *Camera alignment:* At this stage common points are selected on all the photos kept for the processing and matched through the use of photogrammetry software Agisoft Metashape [7]. It also identified the position of the camera for each picture and refined camera calibration parameters. As a result, a sparse point cloud and a set of camera positions were obtained.

- *Building dense point cloud:* The third stage involved the building of a dense point cloud based on the estimated camera positions corrected by the addition of ground control points to “georeferenced” and scale the point cloud. If necessary, a dense point cloud may be further edited and classified before exporting or proceeding to 3D mesh model generation.

- *Building the mesh:* At this stage, the software was used to reconstruct a 3D polygonal mesh representing the object surface based on the dense or sparse point cloud according to the user’s choice. Some corrections, such as mesh decimation, removal of detached components, closing of holes in the mesh, smoothing, were performed.

- *The building texture:* This is the final stage after the mesh geometry was reconstructed, the texture procedure performed and the 3D model created. It can be exported in several digital formats.

Starting from the obtained photogrammetric 3D model, a high resolution (0.226 mm/pixel) scaled orthomosaic was generated. The analysis of the damage was performed by using the ESRI-ArcGIS® software [8]. Three different types of damage were identified: 1) paint completely missing, 2) paint damaged and 3) areas covered with stucco used during a previous restoration. All these areas were delimited and quantified by different polygons.
Figs. 2 and 3 show the two digital models of Lunette 1 and Lunette 2, respectively, which are scaled to measure. Fig. 4 shows the orthomosaic of the Lunette 2 and its damage areas in a GIS environment. In addition, Fig. 2 displays the selected points (point 1, point 2, point 3 and point 4) for XRF investigation.
XRF measurements were performed by using a portable XRF “Alpha 4000” (Innov-X System) analyzer that permitted the detection of chemical elements with an atomic number (Z) between phosphorus and lead. The instrument was equipped with a Ta anode X-ray tube excitation source, and a Si PIN diode detector with an active area of 170 mm^2. The instrument operated in “soil” mode, and two sequential tests were carried out on each analysed area: the first run with operating condition of 40 kV and 7 μA and the second with 15 kV and 5 μA, for a total collection time of 120 s. This configuration allowed us to detect elements from levels of ppm (parts per million). A Hewlett-Packard iPAQ Pocket PC was used to control the instrument and also as data storage. The calibration was carried out by soil LEAP (Light Element Analysis Program) II and was verified using alloy certified reference materials produced by Analytical Reference Materials International. The statistics of the measured spectra was improved by collecting the XRF signal for 60 s per run. Lines detected at ~ 8.15 keV and ~ 9.34 keV, observed for all the investigated samples, were attributed to the L_α and L_β energy transition of Ta anode.

III. RESULTS AND DISCUSSION

The obtained digital models of the two paintings allowed us to measure the whole artifact with high precision as well as the selected parts of interest, giving to the restorers and conservator useful quantitative information that can be used to plan the different restoration phases and, if necessary, to use the digital model for further studies.

In this study, we show that the digital model of the two Lunettes are used to map different features of the two large paintings. The digital model has also been imported on a digital platform to be visualized with modern technologies such as visor for virtual reality to experience it simply and affordably. As shown in Figs. 2 and 3, the two paintings are quite damaged and it was necessary to proper quantify the extent of the degraded area as well as classify the different portions of the paintings according to the different kind of damage.

In particular, Fig. 4 shows, for the Lunette 2, in red the areas where the original paint is completely missing, in yellow the areas where the paint is heavily damaged, and finally, in white the areas covered with stucco used during a previous restoration. The measured total area of the Lunette 2 is 11.54 m^2, the not damaged area is about 75.99% of this value, while the total area affected by damage (and to be heavily restored) is about 24.01%. In particular, the red, yellow and white areas measure 0.94 m^2, 1.76 m^2, 0.064 m^2, respectively.

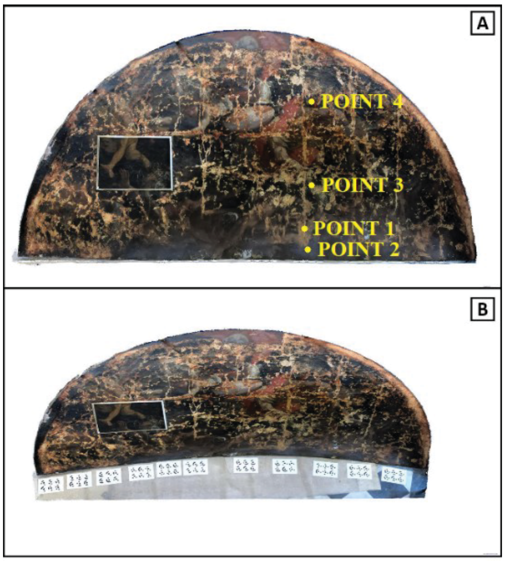

Fig. 2. Digital model of Lunette 1. Selected points (point 1 point 2, point 3 and point 4) for XRF investigation are also shown.

We performed XRF measurements on different areas of the two painted Lunettes, but here we present the preliminary results collected on four different points of Lunette 1 painting, as an example.

Fig. 3. Digital model of Lunette 2.

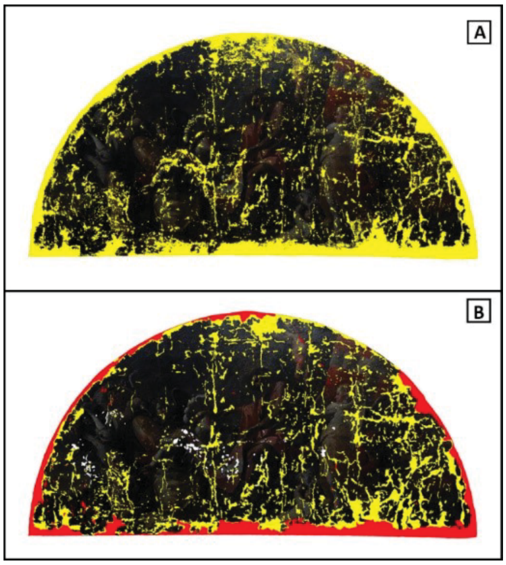

Fig. 4. Digital models of Lunette 2. The top panel shows all damaged areas while the bottom panel classifies the different portions according to the different kind of damage (red areas: paint completely missing, yellow areas: paint damaged, white areas: covered with stucco used during a previous restoration).

Fig. 2(A) displays the analysed points, labeled as point 1, point 2, associated to the preparatory layer (the surface paint layer was, in these points, locally damaged) and, point 3 and point 4, associated to two different pigmented areas, green and black, respectively. The elemental composition of the investigated areas is summarized in Table 1.

Table 1. XRF results for the analyzed points. The key element for pigment identification is marked in bold. The minor or trace elements are presented between brackets.

Description	Point of analysis	XRF elemental composition
Light area, preparatory layer	1	Ca, S, Pb, (Cl, Fe, K, Zn, Sr, Ba)
Dark area, preparatory layer	2	S, Ca, Pb, Cl, Fe, (As, K, Ba, Zn)
Green, sandalwood of *St. Michael*	3	S, Ca, Pb, K, (**Fe**, As, Sb, Ba, Zn, Co, Mn)
Black, angel wing on the right	4	S, **Ca**, Pb, As, Fe, (Sb, Mn, Sr)

In Fig. 5, we display the XRF spectra collected on the light and dark areas of the preparatory layer of the painting (points 1 and 2, respectively).

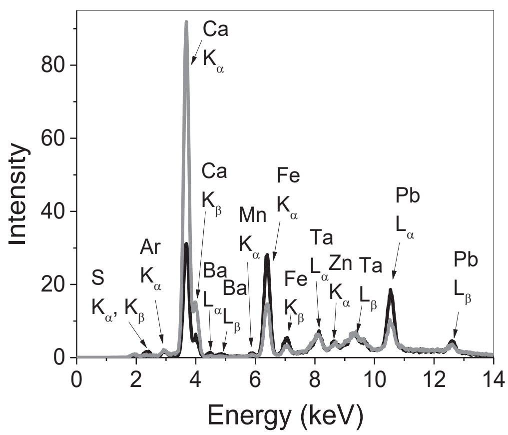

Fig. 5. XRF spectra, in the 0-14 keV range, of the light (point 1, grey line) and dark (point 2, black line) areas of the preparatory layer of Lunette 1.

For both the investigated areas, the detection of S (K_α and K_β transition lines at ~ 2.31 and ~ 2.46 keV, respectively) and Ca (K_α and K_β transition lines at ~ 3.68 and ~ 3.99 keV, respectively) suggests a Ca-based preparation ground, probably made of calcium carbonate ($CaCO_3$) and/or gypsum ($CaSO_4 \cdot 2H_2O$).

Going on, the detection of Pb (L_α and L_β transition lines at ~ 10.55 and ~ 12.61 keV, respectively) could indicate the application of lead white ($(PbCO_3)_2 \cdot Pb(OH)_2$) during the imprinting of the colour. Taking into account that the painting technique of this panel is oil, Pb-based compounds could have been used also as a dryer for the binder [9]. Furthermore, the detection of Ba, in conjunction with Pb, allowed us to hypothesize the presence of a thin layer of white color made up of a mixture of "barium white" ($BaSO_4$), a modern white synthetic compound, and lead white, suggesting the application of modern paints during previous interventions [10]. Worth of note, from the inspection of Fig. 5, the intensity of the peak associated to Ca (representative of the amount of this element) is widely enhanced passing from the dark to the light area, indicating the employment of a Ca-based compound (probably $CaCO_3$) used also for lightening.
As far as the pigmented areas are concerned, in Fig. 6 we report the XRF spectra collected on the green sandalwood of *St. Michael* (point 3, Fig. 6(a)) and on the black wing of the angel on the right side of the painting (point 4, Fig. 6(b)).

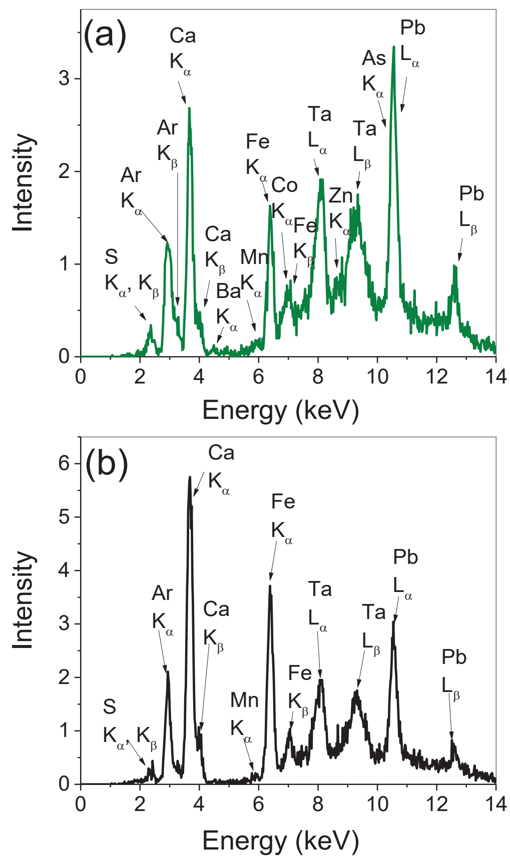

Fig. 6. XRF spectra, in the 0–14 keV range, of (a) the green sandalwood of St. Michael (point 3, green line) and (b) the black wing of the angel on the right side (point 4, black line) of Lunette 1.

The observed XRF transition lines suggest, for the green area, the use of a Fe-based green pigment (probably a green earth) mixed with lead white, in order to get different shades/nuances. Furthermore, traces of Co and Zn were also detected, allowing us to hypothesize the presence of a synthetic Co/Zn-based green pigmenting (probably "cobalt green", $Zn_{1-x}Co_xO$) applied during previous interventions. In the case of the investigated black area (point 4, Fig. 6(b)) the observation of the high peaks ascribed to the K_α (~ 3.68 keV) and K_β (~ 3.99 keV) transition lines of Ca, suggests the use of a Ca-based, organic black pigment, which was probably employed also as color background of the entire upper-section of the painting, for the *St. Michael*'s helmet and for the wings of the angels.

In this case, nevertheless, no further hypothesis can be made by the XRF analysis, considering the low Z number of the characteristic elements. The pigment was probably mixed with a Fe/Mn-based pigment, such as the natural umber ($Fe_2O_3 + MnO_2 + nH_2O + Si + Al_2O_3$), as suggested by the detection, at the same time, of Fe and Mn. Finally, we want to remark that even if the XRF results presented here are preliminary, and the analysis of more points is planned, in all the reported spectra an abundant Ca content can be observed. Despite by means of XRF the distinction among different chemical compounds is not possible, this occurrence supports the hypothesis of the application of the typical Maltese globigerina limestone for the preparation of the painting [11]. This would contribute to date the Lunette 1 painting to the Maltese period of Mattia Preti.

IV. CONCLUSIONS

The present work combines 2D/3D digital reconstructions by photogrammetric survey and XRF spectroscopy in order to get reconstruction and characterize two large Lunettes by Mattia Preti in the *Church of the Immaculate Conception of Sarria* (Floriana, Malta).

These non-invasive methods were applied using portable equipments.

The photogrammetric technique was used to digitally reconstruct the two paintings by Mattia Preti and to create accurate and precise digital models. The models allowed us to quantify the ruined parts on the artifacts and to plan the restoration activities accordingly (at the time of writing, the restorations are near to completion).

XRF technique permitted for a characterization, at elemental scale, of the materials used in the preparatory layer of the painting and possible interventions. Furthermore, two different pigmenting agents were also characterized. We planned a deeper spectroscopic analysis, aimed at a full understanding of the materials used for the formulation of shades and highlights.

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