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THE IMPORTANCE OF A COMPLETE AND MODERN INFORMATION GATHERING PROTOCOL IN THE CONSERVATION PROCESS OF A XVIII-TH CENTURY ICON

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Abstract

The main aim of this paper is present a complete and modern information gathering protocol required in the conservation process of a 18th century wooden icon and to exemplify the importance of permanently implementing new analysis techniques and examination methods in the field of cultural heritage conservation. In order to obtain all the required information for the future restoration process that the icon taken into study will undergo, the following analysis techniques and examination methods were used: OM, SEM-EDX, micro-FTIR, 3D scanning, and RTI (Reflectance Transforming Image). If the classical OM, SEM-EDX and micro-FTIR have allowed us to identify the material used by the author in creating the icon (natural ultramarine blue, red lead), the other two examination techniques have offered the opportunity to generate a digital model of the icon, providing digital information regarding the artwork geometry or the metrical analysis of the surface of the object, and the resource to examine the icon without the risk of handling it again.

Keywords: *Old wood icon; OM; SEM-EDX; micro-FTIR; 3D; RTI*

Introduction

Optical and spectral analysis play a very important role in the scientific investigation of cultural heritage, providing valuable information, in order to identify the materials used by the author, the artwork conservation state, thus creating a proper restoration protocol (compatible materials, structural and chromatic reintegration).

The most important and often used interdisciplinary analysis techniques and examination methods are: optical microscopy (OM), scanning electron microscopy, coupled with energy dispersion X-ray (SEM-EDX), micro-FTIR, Raman, UV/VIS reflectography, etc. [1-13].

Corroborating the results of several techniques and methods provides a researcher the certainty that the obtained results are accurate.

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During the last few years, the field of cultural heritage conservation has experienced an overwhelming need of new techniques capable of providing all the required information for the conservation processes. This fact, combined with the perpetual consideration for the integrity of the artworks, thus the use of non-invasive techniques, has led to the implementation of new techniques for the initial examination of the art piece.

As already mentioned, until now, this initial evaluation was done using techniques and examination methods like optical microscopy, electronic scanning microscopy, etc. But none of this methods provided digital information regarding the artwork geometry or the metrical analysis of the surface of the object.

In order to cover this patch of necessary information, new methods and techniques have emerged, the most important being 3D scanning [14, 15] and RTI (Reflectance Transforming Image) [16, 17]

Until recently, due to technical limitations, these digital techniques were unusable in the painting investigation and conservation field, being implemented mostly when obtaining data from sculptures, buildings, coins, etc., that have a better pronounced 3D surface [18].

Recent technological developments have allowed researchers to use these examination methods for objects that an almost 2D surface, like paintings with great success, thus offering them a more detailed and varied bundle of information [19, 20].

While 3D scanning offers an entire digital model, for an even better observation of the object surface, the RTI examination method is more suitable.

RTI is a computational photographic method that allows the capture of the shape and colour of a surface, also allowing a later interactive illumination of the subject taken into study from every single position.

Invented by Tom Malzbender and Dan Gelb, researchers in the Hewlett-Packard laboratories, this method also offers the possibility to mathematically improve the captured surface image and colour, thus offering information that is not otherwise available through direct examination of the object [16, 17, 21].

The RTI images are created from the information obtained from multiple high resolutions digital photographs of the object, done from a stationary point, while changing the angle and light position (maintain the distance from the object). Each obtained RTI image is similar at a first glance with a bi dimensional photography (2D).This continuous photographic process provides a string of data while uploaded to the software, data then mathematically synthesized in order to obtain a working model on the object surface, which allows the viewer to change the light's position and angle in regards to the object.

The fact that the viewer has this possibility allows him to evaluate the smallest details on the 3D surface of the object [21-24].

Experimental part

Icon presentation

The icon taken into study (Fig. 1), depicts the Virgin Mary holding Baby Jesus in her arms, and was done in egg tempera on a wooden support with a simple animal glue preparation, without the regular canvas so often used in byzantine icons.

The icon's support has the following dimensions: 43×32×2cm, and it's made out of single wood piece, reinforced by back crossbeams.

The wooden support is currently in an advanced state of degradation and deterioration, suffering from xylophagic attacks, cracks, fissures and material loss (around 10% of the original size). An unfinished and improperly executed consolidation processes also contributes to the current conservation state (Fig. 2a-f).

Fig. 1. The icon considered for the study:
Virgin Mary, holding Baby Jesus in her arms.

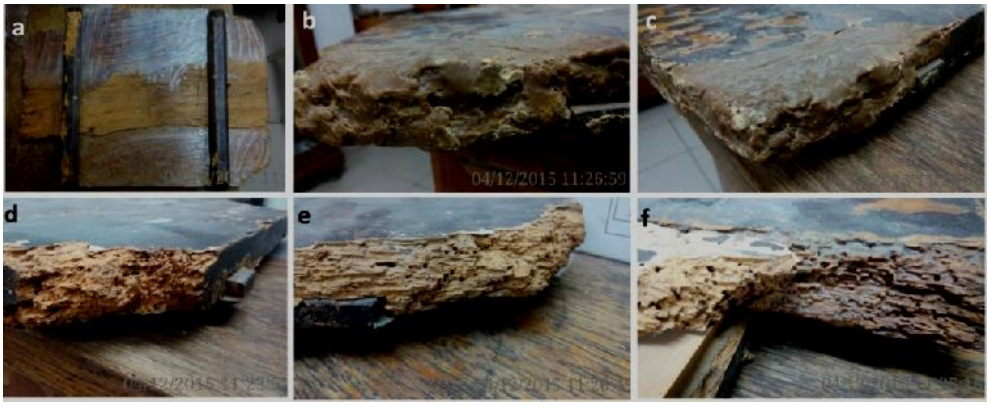

Fig. 2. Details of the wooden support conservation state:
a - unfinished consolidation treatment, using a wax mixture, cracks on the entire length of the support;
b-c - unfinished wax mixture reconstruction; d-f - xylophagic attack, material loss.

The painting layer of the icon also presents a series of deteriorations and degradations: low adherence to the support, gaps, chromatic alterations, dirt gatherings (Fig. 3).

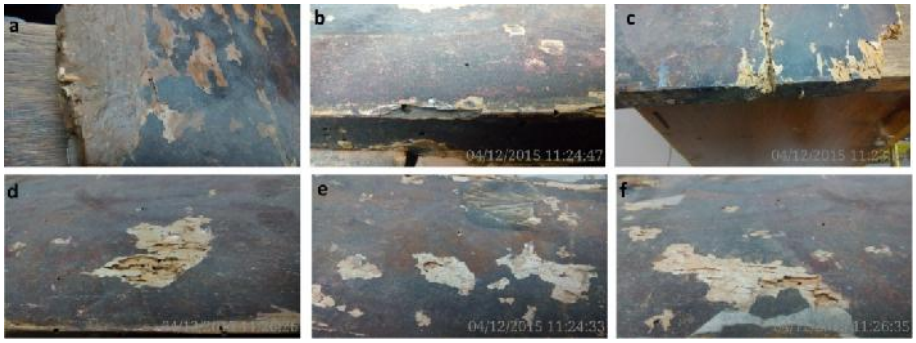

Fig. 3. Deteriorations and degradations of the painting layer: a - gaps, dirt gatherings; b - chromatic alterations; c - cracks and dirt gatherings; d-f - xylophagic attack, deep gaps.

Analysis methods and techniques

In order to determine the materials used by the painter to create the icon, to better understand its compositions so that proper restoration protocols can be chosen, examination methods and analysis techniques were implemented: optical microscopy (OM), scanning electronic microscopy, coupled with energy-dispersive X-ray microanalysis (SEM-EDX), micro-FTIR [25-28], 3D scanning, and RTI.

In order to perform the analysis, five samples were taken from the painting layer of the icon, from areas evidencing a different composition (Fig. 4).

The samples were first examined using a CARL ZEISS AXIO IMAGER A1m light microscope, with an attached AXIOCAM camera, at different magnifications (5×-10×). In order to confirm the data obtained through OM, SEM-EDX analysis was done on the samples, using a VEGA II LSH electronic microscope, made by TESCAN Czech Republic, coupled with an X-ray spectrometer QUANTAX QX2, produced by BRULER/PROENTEC (Germany).

The samples were then further analysed trough micro-FTIR for results confirmation, using a FT-IR spectrometer, coupled with a Hyperion 1000 microscope, both from Brüker optic Equipment, Germany.

Fig. 4. Areas from where the samples were taken: 1 - Virgin Mary's halo; 2 - icon background; 3 - Virgin Mary's face; 4 - Baby Jesus garments; 5 - Virgin Mary's garment; 6 - Sample of previous consolidated support.

In order to create the 3D and the RTI model of the icon taken into study, two different set of photos had to be taken in different condition, using a Nikon DSLR D3300, 24.2 MP was used in setup with a Hama Star 75 photo tripod.

For the 3D model, a number of 70 pictures were taken from all around (360°) the centre of the painting layer of the icon, at approximately the same distance, without using the flash of the camera, in three circles. A constant source of light was used, in order to avoid any changes in the lighting condition of the painting. The photos were then uploaded into the Autodesk 123D Catch software to be processed in order to obtain the 3D copy of the painting layer of our icon. The software automatically finds and matches common features among all of the uploaded photographs in order to create the 3D scene, using the power and speed of cloud computing [15] (Fig. 5).

For the RTI digital model, a set of 35 pictures were taken from a stationary point on top of the icon, with a constant intensity light source, that was moved all around the painting at different angles, in order to obtain as many details of the surface layer (shadows, gaps, deposits). All the pictures taken include a stationary red glossy ball, which will serve as a light reflection tool. The pictures were afterwards processed using Adobe Photoshop Lightroom in order to be enhanced and transformed from .Raw files to .Jpeg in order to be uploaded in RTI builder software [24].

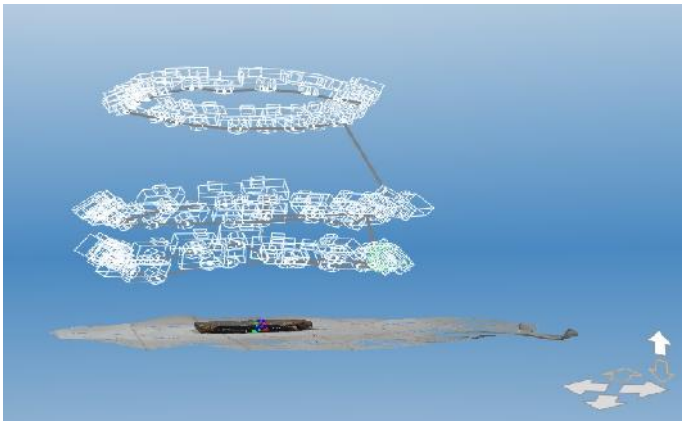

Fig. 5. The three concentric sets of pictures taken for the 3D model.

Results and discussions

For starters, the six samples were examined using the optical microscope (5× and 10× magnification). This examination allowed us to determine the conservation state of the painting layer and structural characteristics of the materials used by the author (pigment granulation).

Sample 1 (taken from the halo of the icon), is most likely done with an ochre pigment mixed with white, in order to obtain a more fade effect. The examination of the sample surface revealed several white particles, mixed with the pigment as a filling material, that wasn't grounded fine enough, and a layer of dirt, still not fixed (Fig. 6a).

Sample 2 has no small gapes or transparency areas, the colour used being most likely a mixture of a red pigment and blue. The sample also presents a much ticker dirt layer and several micro cracks (Fig. 6b).

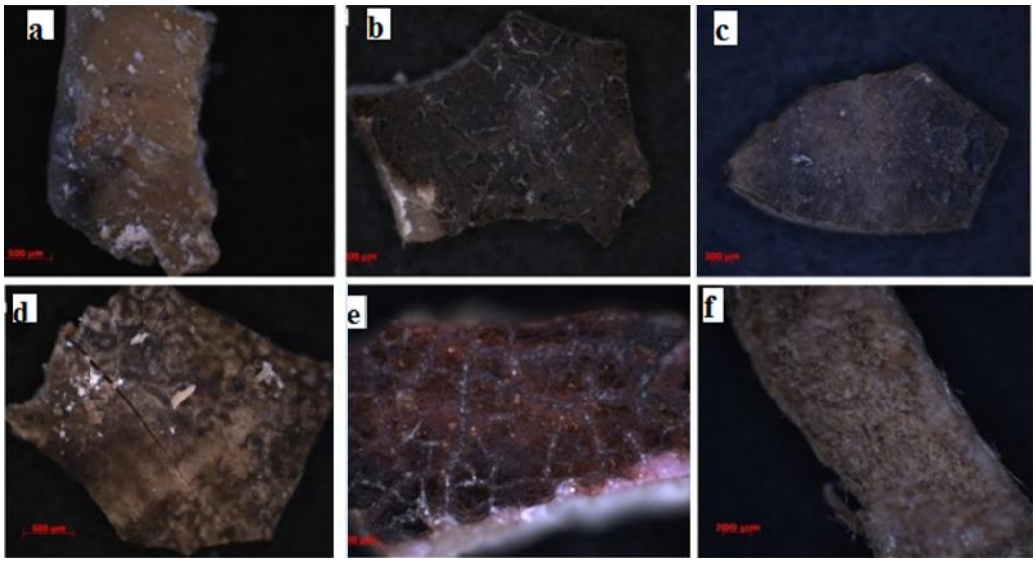

Fig. 6. Optical microscopy: a - Virgin Mary's halo (5×); b - background (5×):
c - Virgin Mary's face (5×); d - Baby Jesus garments (10×);
e - Virgin Mary's garment (10×); f - previously consolidated wood sample (5×).

Sample 3 (taken from the face of *Virgin Mary*) is covered by a thick layer of adherent dirt, but it more compact and has no fine cracks. The same sample also has traces of wax on its surface, which served as a much adherent support for dirt gathering (Fig. 6c).

Sample 4 (taken from Baby Jesus garment) has an unusual pattern on its surface, pattern caused most likely by an improper use of varnish and its ageing process (Fig. 6d).

Sample 5, from an area created most likely with a mixture of red and blue pigments, has an evolving network of cracks, now filled with atmospheric particles, and it's covered with a thick layer of dirt (Fig. 6e).

After examining the last sample, 6, taken from the previously consolidated support area, it was concluded that the penetration degree wasn't optimal, the impregnation being incomplete, with areas still unconsolidated (Fig. 6f).

The same six samples were then analysed through SEM-EDX, in order to identify the chemical elements and the concentration in each sample.

Based on the chemical elements identified and their concentration (table 1), the following pigments were identified for each sample:

1 – iron oxide and lead white, plus earth minerals due to the green earth (Fig. 7a);

2 – ultramarine blue $Na_{8-10}Al_6Si_6O_{24}S_{2-4}$ with red lead Pb3O4 (Fig. 7b);

3 – iron oxide mixed with a earth green pigment (Fig. 7c)

4 – lead white and iron ochre (Fig. 7d)

5 – ultramarine blue $Na_{8-10}Al_6Si_6O_{24}S_{2-4}$ with a red pigment; the presence of K and P was attributed to small quantities of coloured earth added in the mixture (Fig. 7e)

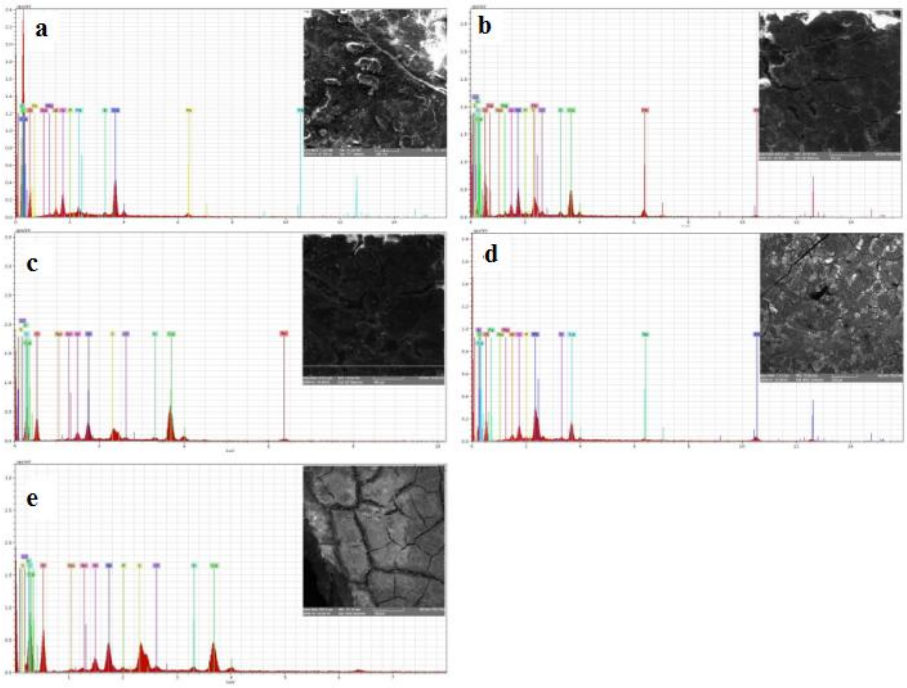

Fig. 7. SEM microphotography and EDX spectrum:
a - sample 1 (200×, SE); b - sample 2 (500×, BSE); 3) sample 3 (500×, SE);
4) sample 4 (200×, BSE); 5) sample 5 (500× BSE).

Table 1. EDX composition of the five samples from the painting layer

Chemical element	Sample 1 [wt.-%]	Sample 2 [wt.-%]	Sample 3 [wt.-%]	Sample 4 [wt.-%]	Sample 5 [wt.-%]
C	15.4932	15.0169	12.1844	9.3857	15.7318
Ca	7.2360	5.4213	6.0927	4.9913	7.1347
Si	3.3718	4.3372	3.4367	2.8524	4.7684
Al	1.5478	2.5615	1.4168	1.3970	2.1679
S	-	0.9929	2.6252	-	4.8382
Na	0.6891	1.6520	0.1925	0.3262	0.3035
P	0.5088	0.4758	-	0.4335	0.8385
Mg	0.7415	1.3669	-	0.5070	-
K	0.7781	0.8531	0.8107	0.6610	0.9349
Fe	1.7008	3.1146	0.2946	1.3083	-
As	-	-	0.4088	-	0.5373
Cl	-	0.6789	0.3539	-	1.1753
Zn	-	-	-	-	-
Ba	-	-	-	-	-
Pb	4.9191	5.7246	-	18.3949	-

Due to the organic nature of the consolidant material used previously, the EDX analysis was inconclusive on the sample taken from the support. Nonetheless, the SEM confirmed the presence of areas that were improperly impregnated (Fig. 8) [29].

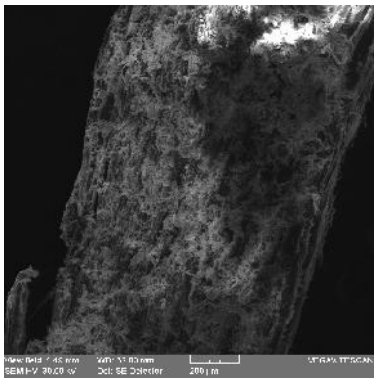

Fig. 8. SEM microphotography of sample 6 (SE, 200×).

The pigments, binders and protection materials used by the author into making this icon where confirmed by micro-FTIR analysis done on all five samples taken from the painting layer of the icon (Fig. 9).

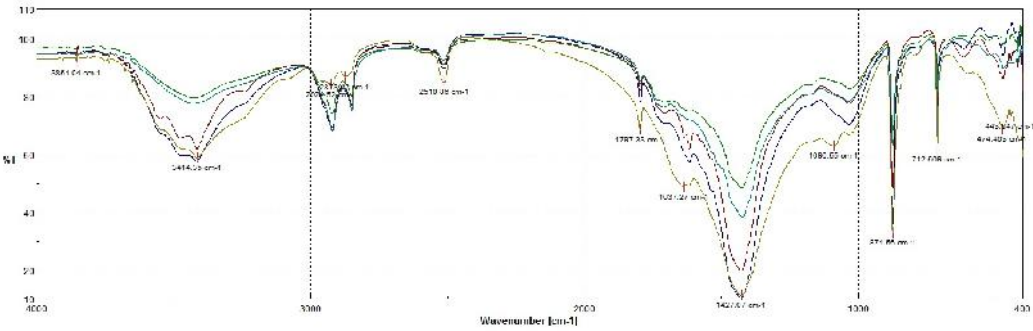

Fig. 9. Micro- FTIR spectrums of the five samples taken from the painting layer: Sample 1- green spectrum; Sample 2 – blue spectrum; Sample 3 – red spectrum; Sample 4 - light blue; Sample 5 – olive spectrum.

First of all, in the samples taken from the painting layer we can observe the absorption bands attributed to the sodalite structure, characteristic for the ultramarine pigments, located around 1010cm^{-1}, in the Si-O stretching area of the aluminosilicates matrix. The same Si-O stretching area also has an asymmetric peak, around 1150cm^{-1} [30].

The calcite spectrum, also known as calcium carbonate, is characterized by a string absorption band around 1420cm^{-1}, due to the out-of-phase stretching of CO_3^{2-}. The narrow band from 710cm^{-1} was attributed to the in-plane deformation of CO_3^{2-}. The bands from around 2510cm^{-1} are also representative for calcium carbonate.

The Al-O vibrations from 550–650cm^{-1}, specific to aluminosilicates were observed predominant in only three samples, as seen in table 2.

The compositional elements of egg emulsion (lipids and proteins) were identified by the presence of several peaks and bands specific to the triglycerides unsaturated esters (–C=O 1600–1700cm^{-1}) [31].

The pure ferric oxide has significant peaks between 400cm^{-1} and 750cm^{-1}, plus a small curve around 610cm^{-1} [32], area that its covered in our case by the Al-O vibrations already mentioned.

The same thing happens with those specific to the lead white pigment. Basic lead micro FTIR shows a strong band near 1410cm^{-1} due to the anti-symmetric stretch of the carbonate group, plus weaker bands near 680 and 1045 cm^{-1} which are due to the carbonate group and a hydroxyl (O-H) stretching band near 3540cm^{-1}, bands and peaks that are covered in our case by those specific to the calcium carbonate.

Table 2. micro-FTIR analysis results

Nr.	Identified pigments	Samples				
		1 sample from the halo (cm^{-1})	2 sample from the background (cm^{-1})	3 sample from the face (cm^{-1})	4 sample from the garment of Baby Jesus (cm^{-1})	5 sample from the garment of Virgin Mary (cm^{-1})
1	**Si-O stretching Natural ultramarine blue pigment**	-	-	1172.51	-	1090.55
2	**Natural ultramarine red pigment**	1032.69	1035.59	1034.62	1037.52	1034.984
3	**Al-O vibrations Aluminosilicates**	-	605.539	613.252	-	606.503
4	**Carbonates (calcium based)- carbonate anion CO_3^{2-}**	1427.07, 875.524, 712.569, 2514,72	1428.99, 875.524, 712.569, 2510.86	1428.99, 875.524, 712.569 2514.72	1426.1, 875.524, 712.569, 2515.09	1427.07, 874.56, 712.569, 2510.86
5	**Hydroxocomplexes-OH, -H-O-H**	3425.92	3416.28, 3543.56	3414.35, 3475.1, 3546.45	3424.96	3414.35
6	**Proteins C-H (2800-3100cm^{-1})**	2850.27, 2919.7	2851.24 2920.66	2850.27 2918.73	2849.31, 2919.7	2873.42 2924.52, 3080.73
7	**Animal glues NH_2 (Amide II band)**	-	1541.81	-	-	-
8	**Egg emulsion -C=O**	1618.673	1617.98, 1703.8,	1617.98, 1637.27, 1700.91	1617.65	1637.27
9	**Damar varnish**	1794.44	1795.4	1700.91, 1794.44	1798.3	1797.33
10	**Yellow/Red ochre**	416.549, 473.439	418.477, 473.439, 781.993	417.513, 443.547, 472.474,	472.474, 414.62	413.656, 443.547, 473.439, 794.528

The final stages of the analysis protocol design to gather all the necessary information for the future restoration protocol of the icon is to create the 3D and RTI model.

In order to start the process of creating the 3D process, all the 70 pictures taken where uploaded to the cloud in order to be computed trough matching varies according to the number of picture (70 being the max number that can be used) and their properties (dimensions, quality, etc.). The obtained 3D model allowed us to establish first of all the point from where the photos were taken and if a certain angle or detail of the painting was not taken into examination (Fig. 10).

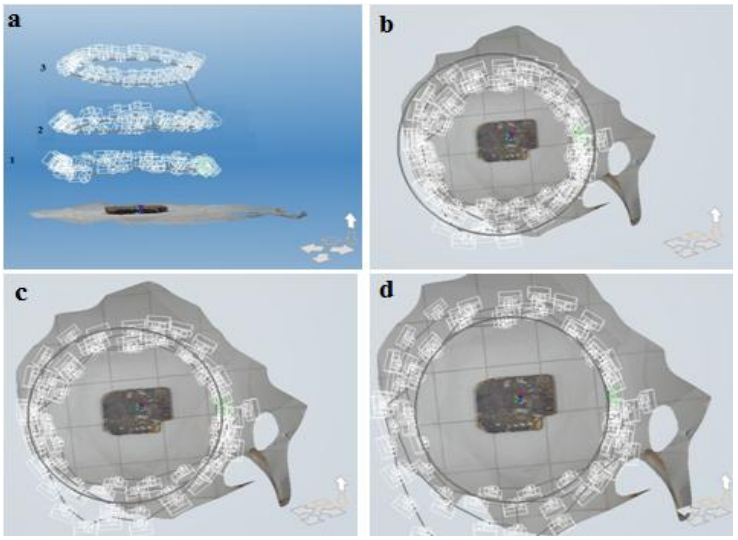

Fig. 10. The radius of the three loops: a - general view of the three loops; b - radius of the last loop; c - radius of the second loop; d - radius of the first loop.

Once we are sure that all the pictures have been matched and the 3D model, the visual examination process of the obtained model can begin. The viewer now has the possibility to observe up close and personally, without actually handling the artwork, its state of conservation and the deteriorations and degradations that affects it (Fig. 11).

Fig. 11. Detail of the Virgin Mary's face.

The viewer also has the opportunity to obtain a 3D structural mesh of the painting, thus allowing him to better map the painting layer gaps (depth and surface) (Fig. 12).

The final step in obtaining the perfect 3D model is background removal, without affecting the actual structure (Fig. 13).

In order to gather even more information about the exact deteriorations and degradations that affect the painting layer of the icon, an RTI model was also created.

As mentioned before, a set of 35 pictures were taken from a stationary point on top of the icon, with a constant intensity light source, that was moved all around the painting at different angles, in order to obtain as many details of the surface layer (shadows, gaps, deposits). All the pictures taken include a stationary red glossy ball, which will serve as a light reflection tool (Fig. 14). The pictures were afterwards processed using Adobe Photoshop

Lightroom in order to be enhanced and transformed from .Raw files to .Jpeg in order to be uploaded in RTI builder software [24].

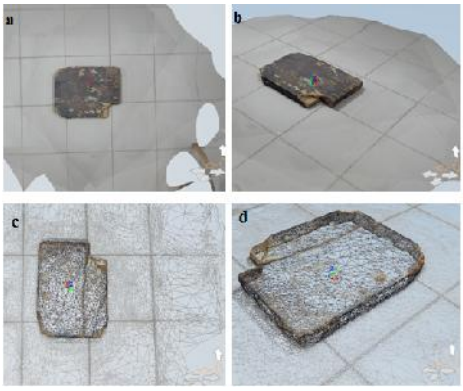

Fig. 12. The obtained 3D model of the icon:
a-b - front and sides; c-d - front and side structure.

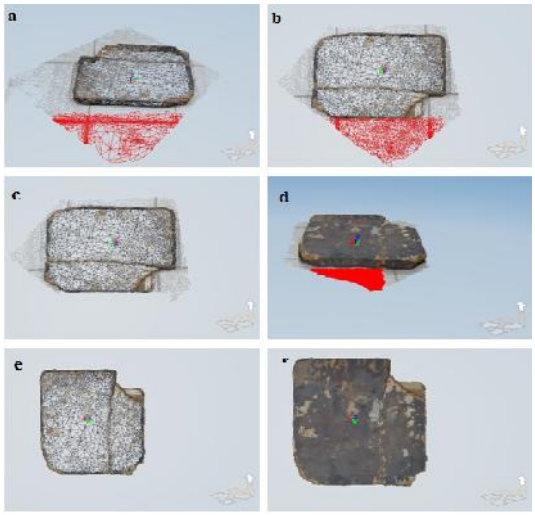

Fig. 13. Stages of background removal.

Fig. 14. Three examples of the photos taken and processed
in order to obtain the RTI model.

Once enhanced and transformed into .Jpeg files, using Adobe Photoshop Lightroom, the photos were selected and uploaded into RTI Builder software, that was already set up to highlight based HSH Fitter. The next step in the RTI model building was the red sphere detection that serves as a support for the highlight detection, followed by the cropping of our interest area, more exactly the painting without the red sphere, which has now served its purpose (Fig. 15a-c). The final execute command creates the RTI file, that can now be opened with the RTI Viewer software (Fig. 15d-f)

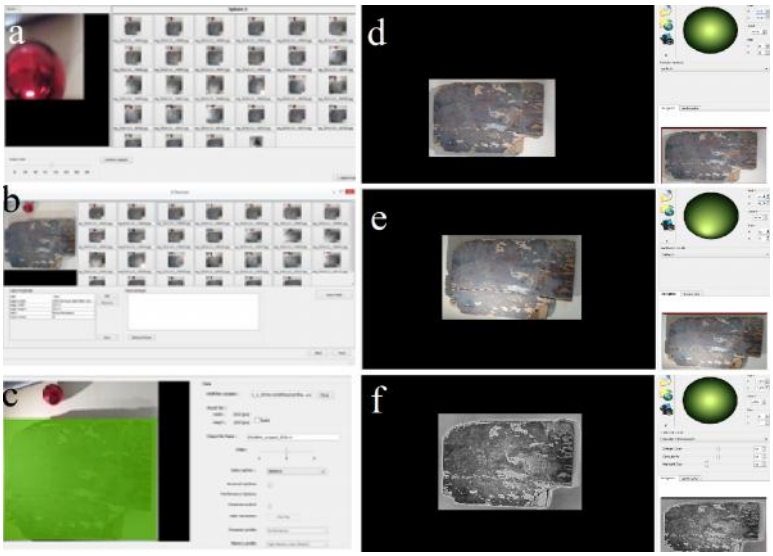

Fig. 15. RTI Technique:
a-c - Stages of RTI Builder; d-f – Stages of RTI Viewer.

Conclusions

The icon taken into study that depicts the *Virgin Mary holding Baby Jesus in her arms* was done in egg tempera on a wooden support with a simple animal glue preparation, without the regular canvas so often used in byzantine icons.

The use of modern analysis techniques, OM, SEM-EDX and micro-FTIR, allowed us to identify the material used by the author in creating the icon (natural ultramarine blue, red lead, iron ochre, lead white). In order to acquire digital information regarding the artwork geometry or the metrical analysis of the surface of the icon, new examination methods were also implemented (3D scanning, RTI), which have offered the opportunity to generate digital model of the icon and the resource to examine the icon without the risk of handling it again.

Implementing new technique analysis and examination methods should represent a never-ending priority for the field of cultural heritage, in the hope of finding new and better solution for preserving the world's cultural heritage.

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