RECH 5 Urbino, Italy

5TH EDITION OF THE INTERNATIONAL MEETING ON RETOUCHING OF CULTURAL HERITAGE

UNIVERSITÀ DEGLI STUDI DI URBINO "CARLO BO"
SCUOLA DI CONSERVAZIONE E RESTAURO DEI BENI CULTURALI

18TH - 19TH OCTOBER 2019

Image analysis applied to the planning of a canvas painting restoration intervention

Amura Annamaria, Landi Luisa, Pisani Luigi, Soro Maria Veronica, Stefano Pagnotta, Zantedeschi Giorgia

Abstract: This work proposes a methodology of digital analysis of the state of conservation of a canvas painting to solve difficulties related to the pictorial reintegration of paintings that present an excessive number of different lacunae in terms of size and extent. The case study is related to the small-size oil on canvas painting executed by an unknown artist, where the lacunae were challenging to analyze and localize graphically. Therefore, it required a careful evaluation of the approach to be used during the pictorial reintegration intervention. Using an image analysis method, based on the semi-automatic extraction approach, the state of conservation's graphic relief outlining different virtual operating proposals was obtained.

Keywords: color reintegration, image analysis, virtual proposals, raster to vector, diagnostic image

Análisis de imagen aplicada a la planificación de una intervención de restauración de pintura sobre lienzo

Resumen: En este trabajo se propone una metodología de análisis digital del estado de conservación de un lienzo con el fin de resolver algunas dificultades relacionadas con la reintegración pictórica de pinturas que presentan un excesivo número de diversas lagunas en términos de tamaño y extensión. El caso de estudio en concreto es un óleo sobre lienzo de pequeño tamaño realizado por un artista desconocido, donde las múltiples áreas con dichas lagunas se caracterizan por bordes complejos difíciles de analizar, clasificar y de localizar gráficamente. Requerían de una evaluación cuidadosa del método a usar durante la intervención de reintegración pictórica. A través del uso de métodos de análisis de imágenes, hemos extraído de forma semiautomática el relieve gráfico del estado de conservación, trazando diferentes propuestas operativas virtuales.

Palabras clave: reintegración de color, análisis de imagen, propuesta virtual, raster para vector, diagnóstico imagen

Análise de imagem aplicada ao planeamento de uma intervenção de restauro de pinturas sobre tela

Resumo: Neste trabalho, propomos um método de análise digital do estado de conservação de uma tela, a fim de resolver algumas dificuldades relacionadas com a reintegração pictórica de pinturas que apresentam um número excessivo de diferentes lacunas em termos de tamanho e comprimento. O estudo de caso concreto é um óleo sobre tela de pequena dimensão realizado por um artista desconhecido, onde as múltiplas áreas com lacunas se caracterizam por bordos complexos, difíceis de analisar, classificar e de localizar graficamente. Requeriam uma avaliação cuidadosa do método a ser utilizado durante a intervenção de reintegração pictórica. Através do uso de métodos de análise de imagem, extraímos semi-automaticamente o gráfico do estado de conservação, trazendo diferentes propostas operacionais virtuais.

Palavras-chave: reintegração de cores, análise de imagem, proposta virtual, raster para vetorial, imagem de diagnóstico

Introduction

Restoring the picture layer gaps is a very sensitive issue in the field of restoration of works on canvas; the main difficulties are related both to the theoretical and practical approach (Brandi 1977). The choices have to be made on the basis of the restoration principles, in order to operate in a non-excessive way that could lead to serious misinterpretation. Therefore, the main decisions to be made include which part has to restore, which pictorial technique to use, whether to use a specific technique or to diversify techniques depending on the type of gaps. The additional difficulties may be encountered when restoring works of art with excessive decay, such as the case study presented in this work, where, in addition to difficulties related to operative choices, difficulties related to the graphical inscription of the conservation status are also present. (Basile 2008, Althofer 2002). In fact, the graphic survey, called "thematic mapping of the artwork", is an extremely important document to register all the operations made on the artwork, and also to facilitate the subsequent intervention of conservation and any future restoration (Sacco 2011). Accordingly, our proposal is to combine the restoration project with the image analysis operations, with the intent of making the analysis of the work of art interactive. Moreover, it can also assist the conservator-restorer in operating in a conscious way and help them in the complex task of graphical inscription of the conservation status. (Amura *et. al*. 2019, Biagi and Maino 2017, Bennardi And Furferi 2007)

Case study

The presented work has been carried out in the restoration laboratory of the University of Urbino. It is related to the oil painting entitled "*Madonna with the Child, Saint Joseph and Saint John*" painted around the second half of the eighteenth century, by an unknown Italian artist and nowadays belonging to a private collection. The artwork was in a very poor state of conservation, the original support has lost its elastic and mechanical properties, resulting in a fragile and rigid outcome. It was realized on a vegetable textile support in linen fiber (analyzed with optical microscope and SEM) in a single sheet and has a plain weave (1: 1) with an average fabric density of 9x9 f / cm2). The central area of the painting was affected by a large cut, extending horizontally side to side, and by other important support gaps as well. Structurally, these lacunae were repaired during the restoration process, using the thread-by-thread tear repair technique (Heiber 2002) [Figure 1 b]. The preparatory layers were affected by an extensive *craquelure*, extending over the entire surface and coinciding with that of the paint layer. The entire painting surface was affected by important adhesion defects, in particular with the support. This resulted in several falls involving both the preparatory and the paint layer which, consequently, brought the artwork to show a large number of lacunae. From the pattern and the localization of the lacunae, it has been assumed that the painting had undergone two different folds: one along the orthogonal directions highlighting a closure "in four", and the other diagonally to indicate the rolling of the painting on itself [Figure 1a]. The heterogeneity of extension and placement of the missing areas required a careful evaluation and the selection of the appropriate integration method. According to a first conservative point of view, the number of lacking materials and their different locations created points of unevenness in the paint system. For this reason, the filling was taken into consideration. However, the visual analysis alone was not sufficient to define the overview of these missing areas in order to define the boundaries within which to apply it. The missing areas were both along the painting edges and localized on figurative elements representing unknown drawings, such as the Madonna with Child, that instead resulted in being recognized as the cloak of the Virgin. Therefore, even the choice of a proper retouching technique was not a simple task.

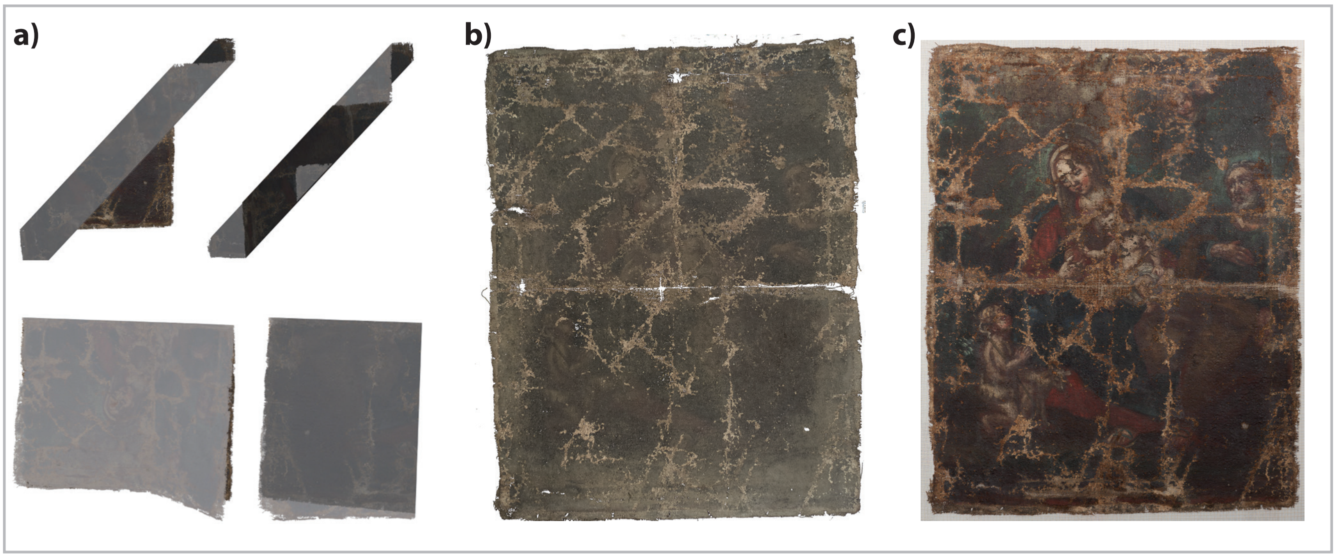

Figure 1.- *Madonna with the Child, Saint Joseph and Saint John* by unknow artist, oil on canvas, second half of the XVIII century, 77x61cm. (a) The hypothesis of two different folds of canvas (b) The painting before restoration (c) The painting after restoration.

Application of image analysis

The main problem to be solved was related to the graphic transcription and the localization of the state of canvas conservation. As the edges of the lacunae were excessively irregular, made the manual transcription very difficult. The first step in obtaining a correct border design, was to initiate a color segmentation algorithm in order to separate the areas of the lacunae and the area of the pictorial film (Tonazzini *et al.* 2019).

—*Image segmentation*

In the presented case study, the color segmentation operations were carried out using the MATLAB© image processing toolbox. To this end, an application called "Image Segmenter", using exclusively a visible-light image, has been used. This application allows the segmentation of an image in various ways, based on the interactive approach by trial and repeat process until the desired result is achieved. As there are various segmentation techniques that work best with particular types of images, the segmentation tool chosen for our case study was "Auto Cluster" - an automatic technique where the application groups image features into a binary segmentation that does not require initialization but uses the Statistics and Machine Learning Toolbox. Using the "Auto Cluster" tool, it is therefore possible to perform an automatic segmentation based on the color differences between the pigmented canvas area and the canvas lacunae. This tool is based on k-means Lloyd's algorithm, in the popular k-means formulation one is given an integer k and a set of n data points in $\mathbb{R}^d$. The goal is to choose k centers so as to minimize Φ, the sum of the squared distances between each point and its closest center. (Arthur And Vassilvitskii 2007). The "Auto Cluster" tool is executed in several steps, converting the image from RGB Color Space to L*a*b* Color Space (also known as CIELAB or CIE L*a*b*) that enables you to quantify visual differences. The L*a*b* color space is derived from the CIE XYZ tristimulus values and consists of a luminosity layer 'L*', chromaticity-layer 'a*' indicating where the color falls along the red-green axis, and chromaticity-layer 'b*' indicating where the color falls along the blue-yellow axis. All of the color information is in the 'a*' and 'b*' layers, therefore it's possible to measure the difference between two colors using the Euclidean distance metric. The tool classifies the colors in 'a*b*' space using k-means clustering. K-means clustering treats each object as having a location in space, it finds partitions so that objects within each cluster are as close to each other as possible, and as far from objects in other clusters as possible. Since the color information exists in the 'a*b*' color space, our objects are pixels with 'a*' and 'b*' values, the Tool converts the data objects into three clusters. The result will be a binary mask in black and white called "binary image", with values 0-1. When using the Auto Cluster segmentation tool, it is possible to include texture as an additional consideration in segmentation. In this case, the application uses Gabor filters to analyze the texture of the image as a preprocessing step in the segmentation (The Mathworks. 2019, Gonzalez and Woods 2012, Stanco et al. 2011, Protiere And Sapiro 2007, Mcandrew A. 2004)

— *Region analyzer*

The binary image obtained was consulted using the "Image region analyzer" application present in the MATLAB© image processing toolbox. This application measures a set of properties for each connected component (also called an object or region) in a binary image next to a table where every row is a region identified in the image and every column is a property of that region, such as the area, perimeter, and orientation. The Image Region Analyzer application uses region props to identify regions in the image and calculates

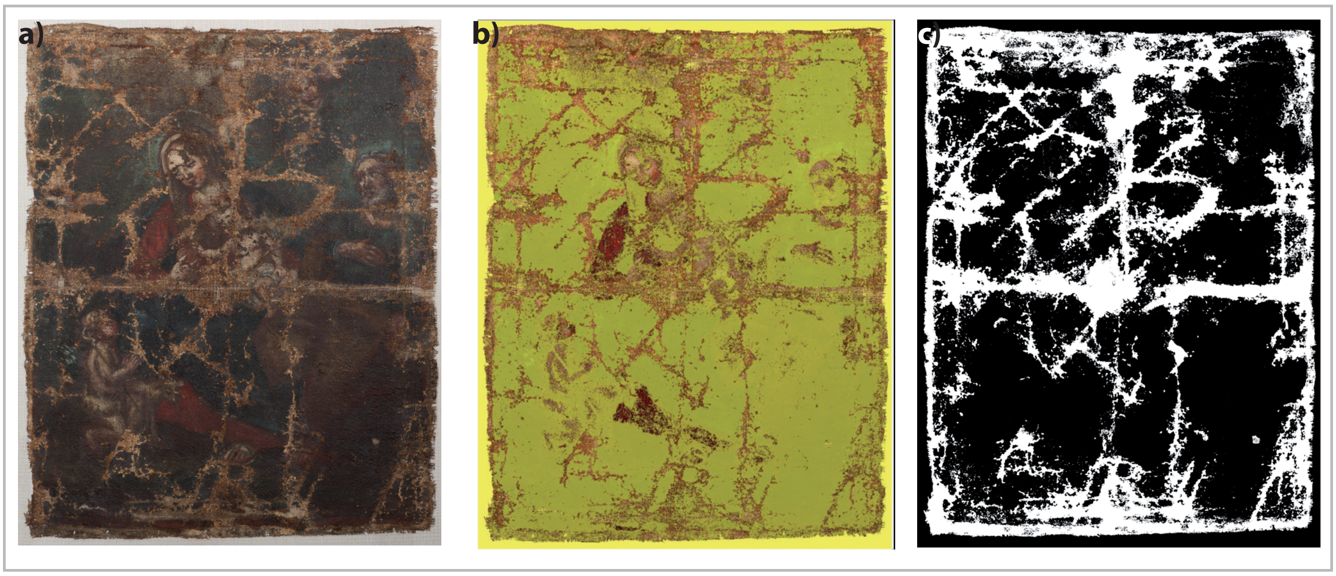

Figure 2.- (a) image in visible light after restoration, (b) image during the "auto cluster" segmentation, (c) binary image in output.

their properties. The properties of the regions can be filtered and queried with Boolean operators, in fact, this application can be used to export an image by filtering only the regions of interest. It's useful to sort the values in the table by property interest to determine what the minimum value should be. The application changes the elements of this dialog box, depending on which criteria is chosen. The criteria for classification of lacunae can therefore be based on percentage statistical analyses of areas or be assessed subjectively by the conservator-restorer, as each case study may require different classifications, not necessarily based on area calculation. In our case, several classification hypotheses have been evaluated, including that of subdividing the gaps into 3 three classes of areas: small, medium and large [Figure 3]. The threshold values of each group of planes were chosen by interrogating the binary image and evaluating the placement of gaps on the canvas surface. A further selection was made by dividing into the group of large gaps those difficult to reintegrate from those easily reintegrated, according to the placement within the representation.(The Mathworks. 2019, Henriques and Gonçalves 2010)

—*Percentage calculation*

The percentage of the lacunae area with respect to the overall area of the canvas has been calculated in order to guide the conservator-restorer during the choice of the intervention technique. Independently of the acquisition spatial resolution, every reproduction of the artwork must respect the original dimensions 1:1 scale, to allow accurate analysis also in digital reality. Only with real measurements can the accurate results be obtained. As every area of the lacunae is represented by pixel size in MATLAB©, the first step is to determine the total area of the lacunae in cm² (AL_c), by suming all the areas of the lacunae pixels (AL_p):

$$AL_p=\sum_{i=1}^{N} AL_i,$$

where AL_i represents the area of i-th lacunae.

The following step is to determine the total surface area of the lacunae in cm2 by the following relation:

$$AC_c : AC_p = x : AL_p$$

$$x = AC_c \times AL_p \;/\; AC_p$$

where AC_c is the Area of Canvas in cm², AC_p is the Area of Canvas in pixel and x is the AT_c total area of the lacunae in cm², leading to the value of areas expressed in terms of cm² or percentage:

$$AT_c{:}AC_c{=}x{:}100$$

Table 1.- Canvas area and lacunae in 300 pixel per inch resolution

CANVAS AREA AND LACUNAE IN 300 PIXEL PER INCH RESOLUTION		
CANVAS	**cm**	**pixel**
(AC) Canvas Area	(AC_c) 4.534 cm²	(AC_p) 65522270 Pixel
LACUNAE	**cm**	**pixel**
(AL) Lacunae Area	(AL_c)1.334 cm²	(AL_p)18610183 Pixel

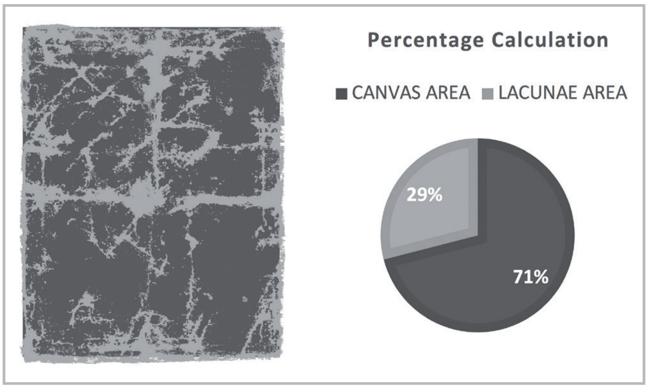

Figure 4.- Percentage of the Lacunae area respect to the overall area of the canvas.

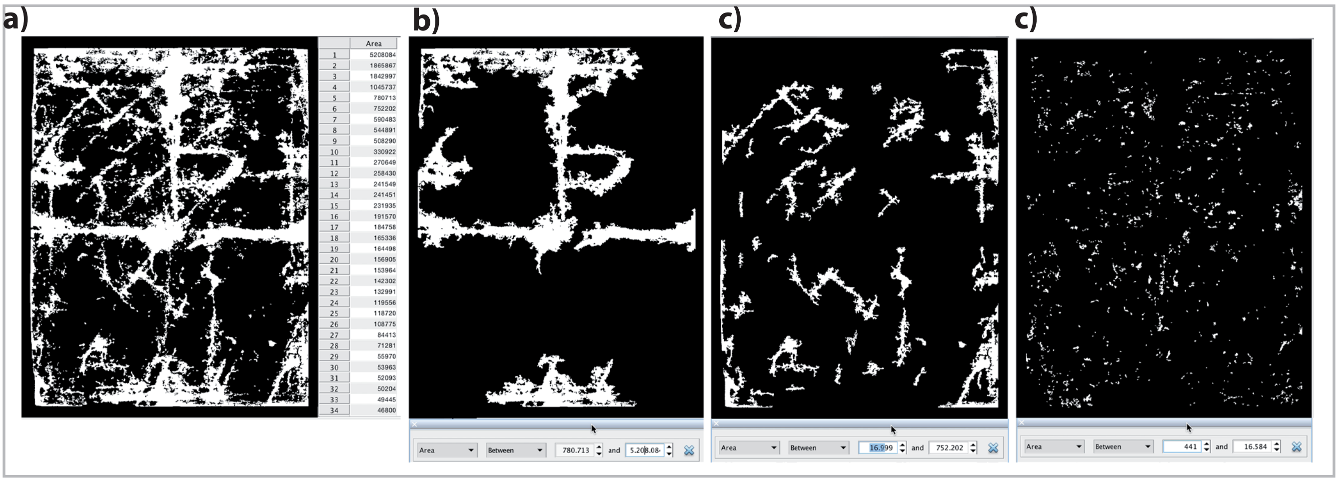

Figure 3.- (a) Binary image obtained with all areas of the lacunae visible, lacunae classification with (b) large areas, (c) medium areas, (d) small areas.

—Mean zonal statistics analysis

The virtual pictorial reintegration proposals were created choosing the neutral tones from a zonal statistical mean function in MatLab©. We then calculated the mean value of the entire area of the canvas excluding the space of the lacerations, which did not present pigment, obtaining a set of three RGB values (M_v RGB), that represent the average of the colored pigments existing on the canvas [Figure 5]. (The Mathworks. 2019) For a random variable vector A made up of N scalar observations, the mean is defined as

$$\mu = \frac{1}{N}\sum_{i=N}^{N} A_i$$

then the mean of the RGB values can be represented with the following expression, where M corresponds to the mean and v to the values:

$$M_v\ RGB = \left[M_{Rv} = \frac{1}{N}\sum_{i=1}^{N} R_i\ , M_{Gv} = \frac{1}{N}\sum_{i=1}^{N} G_i\ , M_{Bv} = \frac{1}{N}\sum_{i=1}^{N} B_i \right]$$

$$M_v\ RGB = \lfloor R = M_{Rv}\ , G = M_{Gv}\ , B = M_{Bv} \rfloor$$

The pictorial reintegration proposals of the lacunae have been realized using Adobe Photoshop CC2019©, using the "replacing color" technique, changing the RGB values of the lacunae with the values obtained from the mean. Binary masks were used to select and replace only the pixels of the areas concerned (Adobe® Photoshop® CC Help, Last updated 2/2/2018)

Intervention proposals

The result of the statistical analysis provided us with an objective and highly detailed survey and the data obtained from the statistical evaluations highlighted that the percentage of missing areas (approximately 29%) was excessively high for filling the complete missing areas. As this would result in almost a third of the total surface area covered by filling, due to a large quantity of additional material would have added a lot of weight on the support and would thus possibly cause an excessive withdrawal affecting the painting. At this point, the decision has been made to proceed from the perspective of the retouching phase, thereby advancing and evaluating the different possibilities of pictorial integration through the hypothesis of virtual intervention (Kunzelman *et al.* 2010).

Thus, the investigation of the lacunae has been carried out in a differentiated way according to the area of the work concerned and its size, always detected by computerized methods (Bracco *et al.* (2002). The analysis of the lacunae size has been done by taking the central area of the work concerning the Madonna and a Child as the model for the complex cases of lacunae involved, and hence used to determine the intervention method to be applied to the complete painting. The virtual reintegration process was carried out in several steps, using different techniques. The first one was to use complete white filling to simulate a chalk and glue one, as depicted in [Figure 5 b], followed by an integration with neutral tones obtained from the mean of the pictorial film. Taking that as a model we applied a lighter neutral tone to the exposed canvas and an additional neutral tone laid on a texturized filling similar to that of the *craquele*, as showed on [Figure 5 c].

However, as the results was not visually appealing, the decision has been made to "close" the smallest lacunae. As these were localized mostly in the background and were characterized by easy to integrate flat and uniform folds of color, the mimetic integration technique was chosen. That enabled the elimination of the visual discomfort and to proceed to the analysis of the remaining of the lacunae

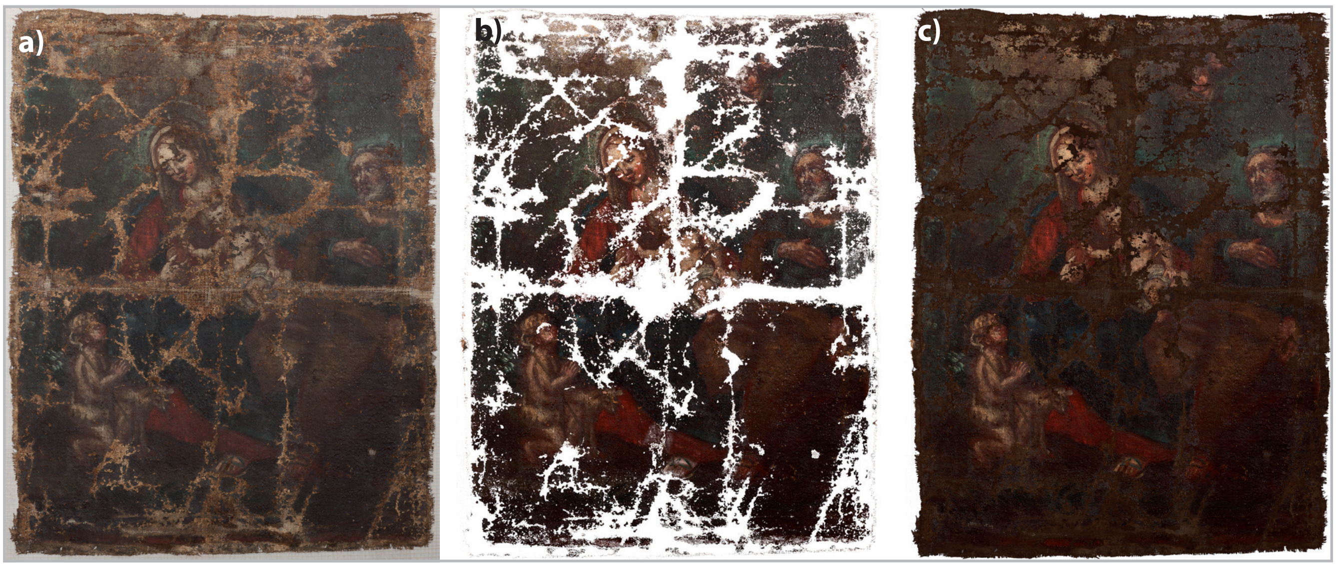

Figure 5.- (a) image in visible light after restoration (consolidation, support repair and cleaning of paint layer) (b) Virtual processing, white filling, (c) The resultant color obtained by the statistical zonal mean of the RGB values, after virtual processing.

Figure 6.- (a) Closure of small lacunae with mimetic integration (b) Closure of medium and big lacunae with mimetic integration, except the central lacuna. (c) Closure all the lacunae with mimetic integration and closure whit neutral tone the central lacuna.

[Figure 6 a]. Treating the lacunae classified as "small" using the mimetic pictorial integration, several proposals for the medium and big lacunae were created:

1) a neutral tone,
2) mimetic tone for the medium lacunae and a neutral tone for the big lacunae.

Finally, in order to differentiate only the central lacuna, as its dimension was substantial, as well as it concerned figurative elements that could not be reconstructed, the mimetic integration has been applied to small, medium and big lacunae localized only to the background. This approach was considered possible because the areas were on flat chromatic surfaces including figurative elements representing drawings that were possible to recognize (Brandi 1977). For the central lacuna a neutral tone was proposed in addition to leaving the canvas exposed. The result can be seen on Figure 6.

Table 2.- Process elaboration time of our specific case study

OPERATIONS IN MATLAB	USER EXPERT	MIDDLE USER
Image Segmentation	10 min	20 min
Region analyzer	5 min	10 min
Percentage calculation	10 min	15/20 min
Mean zonal statistics analysis	5 min	15 min
Intervention Proposals in Photoshop	10 min	20 min
	Total 40 min	Total 80/85 min

Conclusions

The image analysis enables a statistical analysis of the data and an objective transcription of the conservation status of the canvas, even in the situations where the works of art show excessive superficial and structural degradation. The described operations are a part of a semi-automatic features extraction methodology developed during a research doctorate project at the University of Urbino. The presented methodology is currently executable on a MATLAB© QGIS© software (Amura *et al.* 2019). Moreover, through the virtual system it was possible to elaborate different hypotheses of integration, which gave us the possibility to evaluate in advance the effectiveness of one particular intervention approach over another. This enables a realistic prediction of the integration operation, and also to outline the final restoration plan for the artwork.

References

Adobe® Photoshop® CC Help, (Last updated 2/2/2018), pp.361-363, 471- 473. Available at: https://helpx.adobe.com/pdf/photoshop_reference.pdf, [accessed 29/06/2020].

ALTHOFER H. (2002). *La questione del ritocco nel restauro pittorico*. Padova: Il Prato Editore.

AMURA A. *et al.* (2020). "Color Segmentation and Neural Networks for Automatic Graphic Relief of the State of Conservation of Artworks." *Color Culture and Science Journal* 12(2): 07–15. http://jcolore.gruppodelcolore.it/ojs/index.php/CCSJ/article/view/CCSJ.120201 (September 16, 2020).

ARTHUR, D. and VASSILVITSKII S. (2007). "K-means++: The Advantages of Careful Seeding", in SODA '07: *Proceedings of the Eighteenth Annual ACM-SIAM Symposium on Discrete Algorithms*. New Orleans, LA. pp. 1027–1035.

BASILE, G. (2008). *La storia del restauro dell'Annunciazione di Antonello da Messina*. Available at: http://www.giuseppebasile.org/restauri/l-annunciazione-di-antonello-da-messina/1-la-storia-del-restauro-dell-annunciazione-di-antonello-da-messina, [accessed 29/06/2020].

BENNARDI D., FURFERI R. (2007). I*l restauro Virtuale, tra ideologia e metodologia*. Firenze: Edifir Editore.

BIAGI MAINO D., MAINO G. (2017). *Principi e applicazioni del restauro virtuale*. Collana: Studi Storia e Teoria del Restauro n°29. Firenze: Edifir Edizioni.

HEIBER, W. (2002). Thread-by-thread tear mending workshop, in *Painting section Conservation News*, 77: 38-39.

BRACCO, P. *et al.*, (2002). "Caravaggio: l'incoronazione di spine' e il suo doppio", in *OPD Restauro*, 14: 13-42, https://www.jstor.org/stable/24395142.

BRANDI C. (1977). *Teoria del Restauro*. Torino: Enaudi editore.

GONZALEZ R.C., WOODS R.E. (2012). *Elaborazione delle immagini digitali*. (III ed.). Pavia: Pearson Pavia Bruno Mondadori S.p.A.

HENRIQUES, F., GONÇALVES A. (2010). "Analysis of lacunae and retouching areas in panel paintings using landscape metrics" in: *Digital Heritage: Third International Euro-Mediterranean Conference*, 99-109.

KUNZELMAN, D. *et al.* (2010). "Immaginare il restauro: l'integrità pittorica del dipinto visualizzata grazie al ritocco virtuale" in *Le fasi finali nel restauro delle opere policrome mobili, Atti del congresso internazionale "Colore e Conservazione", Materiali e metodi nel restauro delle opere policrome mobili*, Trento 19-20/11/2010, CESMAR7, Il prato, 137-144.

McANDREW A. (2004). "An introduction to digital image processing with MatLab", *Notes for scm2511 image processing*, School of Computer Science and Mathematics, Victoria University of Technology, 264 (1). Available at: http://www.math.hkbu.edu.hk/~zeng/Teaching/math3615/ls.pdf, [accessed 29/06/2020].

PROTIERE A. and SAPIRO G. (2007). "Interactive Image Segmentation via Adaptive Weighted Distances" in *IEEE Transactions on Image Processing*, 16 (4): 1046-1057, https://doi.org/10.1109/TIP.2007.891796.

SACCO, F. (2002). "Sistematica della documentazione e progetto di restauro", *Bollettino ICR*, N.S. 4(1): 28-54.

STANCO F. *et al.* (2011). *Digital Imaging for Cultural Heritage Preservation: Analysis, Restoration and Reconstruction of Ancient Artworks*. CRC Press.

THE MATHWORKS. (2019). *Image Processing Toolbox*™ User's Guide, R2019b, © COPYRIGHT 1993–2019 by The MathWorks, Inc., 13-136.

TONAZZINI, A. et al. (2019). "Analytical and mathematical methods for revealing hidden details in ancient manuscripts and paintings" in *Journal of Advanced Research*, 17: 31-42, https://doi.org/10.1016/j.jare.2019.01.003.

Author/s

Amura Annamaria
annamaria.amura@uniurb.it
Department of Pure and Applied Sciences
University of Urbino Caro Bo.

Amura Annamaria is a Ph.D. Candidate in Computer Science at University of Urbino with a research project in "Digital Image Analysis for the Automation of Graphic Documentation of Cultural Heritage." She has had several teaching supports contracts in computer science and design courses. She has a B.d. in Technology for the Conservation and Restoration of Cultural Heritage, Class 41, and a M.d. in Graphics of Images, LM12, Documentation and Photography for Cultural Heritage. Her research interests include digital photography, Image analysis, features extraction from diagnostic Images, raster to vector automation method, GIS database, virtual restoration, Graphic documentation.

Landi Luisa
luisa.landi@uniurb.it
School of Conservation and Restoration, Department of Basic Sciences and Applications, University of Urbino Carlo Bo, Italy

Landi Luisa Graduated in 2004 at the Opificio delle Pietre Dure in Florence, she carries out restoration and conservation of artistic assets for public and private institutions in Florence. Since 2011 she is a contract professor at the Faculty of Science and Technology - Single-cycle master's degree in Conservation and Restoration of Cultural Heritage of the University of Urbino.

Pisani Luigi
lluigi.pisani@uniurb.it
School of Conservation and Restoration, Department of Basic Sciences and Applications, University of Urbino Carlo Bo, Italy

Pisani Luigi restorer since 1987 lecturer at the University of Conservation and Restoration of Cultural Heritage Urbino. Taking care of structural problems of works of art in wood and oil on canvas. - Responsible deposit for post-earthquake art authorized Mibac-Amandola (FM) The main restorations: -St John's Co-Cathedral in Valletta (Malta) Oil on canvas the Conversion of Saint Paul by Mattia Preti -Oil on canvas Madonna and Child with Saints by Simone de Magistris -San Ginesio (MC) - The Vaccai theater in Tolentino (MC) after the fire, - The Tarsias of the Renaissance choir of the Lendinara Canozi in San Pietro (Modena).

Soro Maria Veronica
sorove@libero.it
School of Conservation and Restoration, Department of Basic Sciences and Applications, University of Urbino Carlo Bo, Italy

https://doi.org/10.37558/gec.v18i1.822

Soro Maria Veronica is a restorer just graduated from the University of Urbino with a dissertation project that analyses the preparatory drawings and sketches on canvas that the painter Arturo Gatti used for the creation of Polish Chapel decorations located in the Basilica of Loreto. In addition to the specialization in restoration of painting on canvas, wooden sculptures, panel paintings and mixed media (contemporary arts) that she obtained during the five-year Master Degree in "Conservation and Restoration of Cultural Heritage" from the University of Urbino, she also has a Degree in "Preservation of Cultural Heritage" from the University of Bologna.

Zantedeschi Giorgia
gio.zante@hotmail.it
Applied and Laser Spectroscopy Laboratory, Institute of Chemistry of Organometallic Compounds, Research Area of National Research Council, Pisa, Italy

Zantedeschi Giorgia is an undergraduate student of the five-year master's degree in "Conservation and Restoration of Cultural Heritage" of the "Carlo Bo" University of Urbino, which is specialized in canvas painting, wood sculptures and painting and mixed media (contemporary arts) restoration. She also attended the degree course in "Conservation, Restauration des oeuvres d'art" of the Academy "Esa Saint Luc" of Liege for a year (European Erasmus project). The thesis project in which she is engaged, concerns the conservation and restoration spaces of contemporary art collections and takes the "Enea Righi Collection" as case study.

Stefano Pagnotta
stefanopagnotta@yahoo.it
Civilization and Form of Knowledge Department, University of Pisa, Italy

Dr. Pagnotta is editorial board member of Anthropology Open Journal, review board member of MDPI Minerals Journal and "Cultore della Materia" in Archaeology at University of Pisa. PhD in Earth Sciences, Md in Archaeology and Bd in Conservation of Cultural Heritage. He is research fellow at ICCOM CNR. Visiting scientist at the Institut für Chemie in Potsdam, at the Pure and Applied Science Department University of Urbino and at the Vinča Nuclear Institute. Author of more than 50 paper in international peer reviewed journals with an h-index of 10.