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11. Color and Education. Pedagogy, didactics of color, aesthetic education, artistic education.
12. Color and Communication/Marketing. Graphics, communication, packaging, lettering, exposure, advertising.

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Renata Pompas

Editorial

Dear Readers, with vol 12 n. 2 we close the seventh year of CCSJ. Since 2019 the CCSJ website is available via the Open Journal System. This allows a better indexing of the published articles and will guarantee the compatibility with Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH). In 2020, despite the severe Covid19 crisis, we continued with the publishing activities and we refined our archiving policy to guarantee long-term access of our issues, making agreements with the Biblioteca Nazionale Centrale di Firenze. Since 2014 we have published 12 volumes for a total of 14 issues. Since 2015 we have applied the double blind peer review and since 2016 we have applied the DOI system. It is also useful to recall the importance of the concept of “diamond open access” under which our journal is published: the journal is completely free for both readers and authors. This is possible thanks to the voluntary support of the members of the "Associazione Italiana Colore" who work in the editorial committee, thanks to the associate editors, thanks to the deputy editor Alessandro Rizzi and the President of Associazione Italiana Colore Marcello Picollo. A special thanks goes to Chiara Storti of the Biblioteca Nazionale Centrale di Firenze (BNCF) the main official library of Italy, to Filippo Cherubini of IFAC-CNR who manages the Open Journal System, to Veronica Marchiafava, the secretary of our association, for the management of DOI database and to Andrea Sinicalco, the vice-president of our association, for the graphic support. Many of these people are also involved in the organizing committee of the important meeting in 2021: the AIC 14th Congress that will be held for the first time in Italy organized by the Associazione Italiana Colore (www.aic2021.org).

The peculiarity of our journal, also written in the statute of our publisher, the Associazione Italiana Colore, is to collect papers on color and related areas in a multidisciplinary way. This basically means that in our peer review process we could have papers ranging from the science of colorimetry to the culture of color in the history of art. Moreover, these papers have very different styles and ways of writing, as diverse is the group of the peer reviewers that constitutes our editorial board. The CCSJ accept papers on a wide range of topics on color, including and not limited to the following:

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4. Color and Physiology. Mechanisms of vision in their experimental and theoretical aspects, color vision and color appearance, deficiencies, abnormalities, clinical and biological aspects, synesthesia, health, well-being.

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In an era in which sectoral super-specialisation has reached extreme limits, having a multidisciplinary journal, on a multidisciplinary theme such as color, favors the development of problem solving skills that are based on the psychological methodologies of lateral thinking.

July, 2020
The Editor-in-Chief
Maurizio Rossi
Full professor of Lighting Design and Design Methods
Politecnico di Milano

Color segmentation and neural networks for automatic graphic relief of the state of conservation of artworks

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ABSTRACT

This paper proposes a semi-automated methodology based on a sequence of analysis processes performed on multispectral images of artworks and aimed at the extraction of vector maps regarding their state of conservation. The graphic relief of the artwork represents the main instrument of communication and synthesis of information and data acquired on cultural heritage during restoration. Despite the widespread use of informatics tools, currently, these operations are still extremely subjective and require high execution times and costs. In some cases, manual execution is particularly complicated and almost impossible to carry out. The methodology proposed here allows supervised, partial automation of these procedures avoids approximations and drastically reduces the work times, as it makes a vector drawing by extracting the areas directly from the raster images. We propose a procedure for color segmentation based on principal/independent component analysis (PCA/ICA) and SOM neural networks and, as a case study, present the results obtained on a set of multispectral reproductions of a painting on canvas.

KEYWORDS Multispectral images, Segmentation algorithms, Image analysis, Shape representation and analysis, Cultural heritage, Raster to vector, Neural networks

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1. Introduction

All the disciplines connected to restoration have always shown a deep need to achieve an extensive understanding of the object of interest, in order to develop a greater awareness of the actions needed and to perform them in the full respect of the object features. This knowledge can only be acquired through the study of the artwork's artistic and conservative history and the techniques and materials used for its realization. Several factors contribute to the realization of a restoration project, involving theory and methodology based on the relevant regulations (in Italy, issued by the Central Cataloging and Documentation Institute, iccd.beniculturali.it). Based on these regulations, all restoration interventions must be preceded and accompanied by documentation to create a sort of "medical record" of the artwork, within which all the collected data must be transcribed and archived in different forms and standard and geometrically correct modalities (The Venice Charter 1964) (Sacco 2002). At this cognitive stage, an important role is played by the transcription in graphics drawings of all the information obtained on the artwork. These graphics drawings, called *graphic relief* or *thematic maps*, are the primary tool for communication and synthesis of the collected data and are structured in categories and subcategories. The thematic maps are formed by two graphically distinct models using different textures and colors and associated with a legend: 1. *The artwork model* is the graphic representation of the shape of the artwork and its figurative symbology; 2. *The information model* is the graphical description of the information regarding conservative historical data (Sacco 2002). It is worth observing that currently, the graphic transcription of the data is performed manually by the restorer, and the multispectral images used for the localization of the information, are inspected only visually, or at most are optimized through a preprocessing by the experts (Dyer, J. et al. 2013). The level of detail of each graphic relief is different from any other, and the edges of the areas that contain the information of interest are often very complex to be transcribed. The restorers often rely on architects for the architectural graphic relief or use commercial software without a standard methodology. In 2003, the web-based information system SICaR was created for the georeferenced documentation within the network of the Italian restoration sites (sicar.beniculturali.it). Unfortunately, no image analysis tools are included in this software. This means that the graphic reliefs are performed by manually tracing the relevant areas with drawing tools, no image analysis strategy can be used to extract the relevant information, and no interaction is possible between the raster images and the vector

graphics to help compile the thematic maps. In cultural heritage, the interest has focused recently on 3D modeling operations, image processing and artificial vision (Apollonio et al. 2017) (Tonazzini et al. 2019a, b) (Grifoni et al. 2019) (Vallet, J.M. et al. 2012) (Grilli, E. (2019). However, the authorities in charge of the conservation of cultural heritage (the Italian Ministry of Cultural Heritage, for example) still require graphic reliefs based on photographs. This motivates the quest we are pursuing for a standardizable methodology to separate and extract the relevant areas of interest from the raster images (photographs, etc.), then vectorize their boundaries and synthesize the results in the documents required by the authorities. A number of suitable image analysis methodologies must be selected that can solve, at least in part, the problems of reading and transcribing data. Besides avoiding results that are prone to personal biases, a partial automatization of this process can also reduce significantly the burden associated with the most time-consuming tasks. The method we are proposing here is based on our consolidated toolbox for the analysis of multispectral images. Spectrally discernable areas in the artwork image can be separated through statistical techniques such as principal component analysis or independent component analysis, and with the help of dedicated neural networks. With the essential contribution of the human expert, the areas relevant to the documentation are then recognized and segmented with the help of a dedicated image analysis process. The latter extracts semi-automatically the areas, separating them into different regions of interest (ROI), each corresponding to specific information attributable to the executive, restoration, and conservation history of the painting. The ROIs are then vectorized and used in graphic relief. This process is more objective and repeatable than any manual solution, and also enable the user better to perform geometric and statistical measurements on the resulting drawing.

2. Case study

The procedure described above has proved to be effective in different cases and with different restoration objectives. We demonstrate it here as applied to a canvas depicting queen Cleopatra, attributed to Donato Creti (Fig 1 a). This *opera* was donated to a private family by Pope Leo XII on 27 August 1827. Its last restoration intervention was executed in 2019 when the restorers discovered several pictorials *pentimenti* [1] executed by the author and several mimetic pictorials retouched executed after his death by unknown artists or restorers. Donato Creti used to repaint the subjects: his contemporary painter, the art historian Giampietro

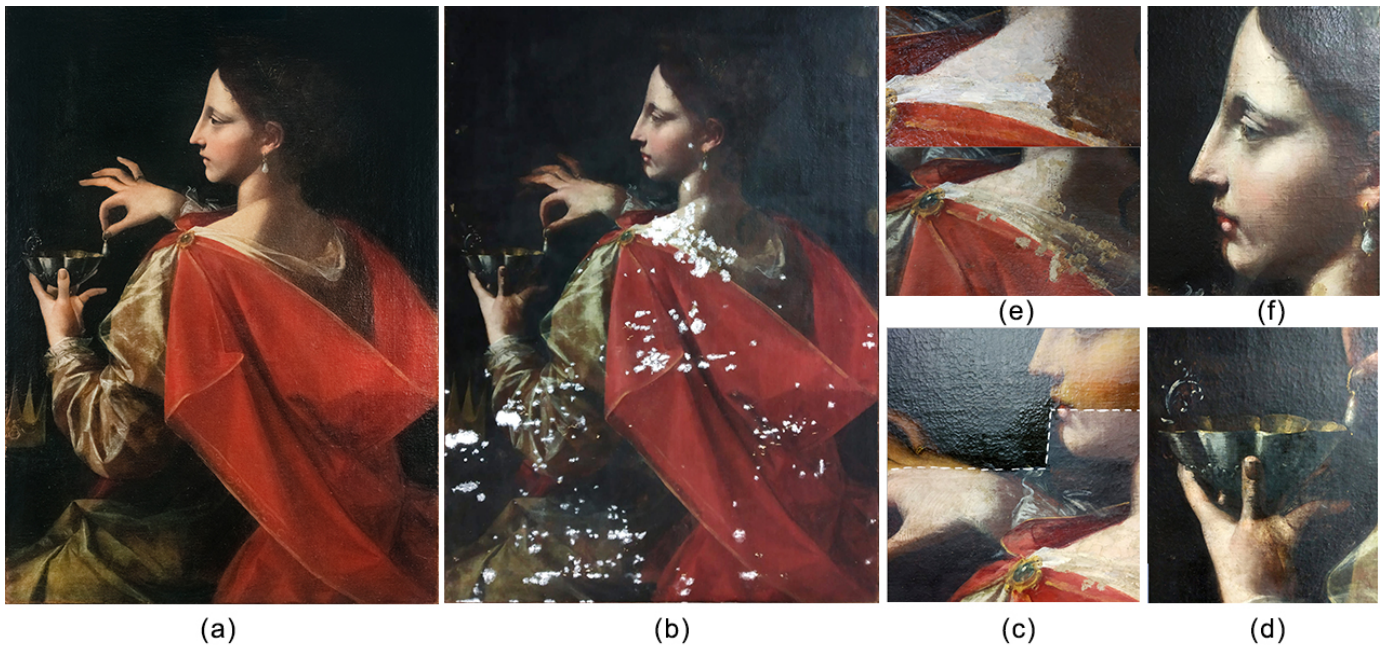


Fig 1 (a) *Cleopatra* by Donato Creti (Cremona 1671, Bologna 1749), oil on canvas, 100×77 cm. Standard RGB; after the restoration intervention, (b) image captured during the restoration. Gaps covered by white stucco in 2019; (c) Removal of old varnish; (e) Old gaps from previous restorations and retouches not performed by the original artist. (f) (d) Pictorial pentimenti made by the artist in profile and left hand.

Zanotti, says that – “for his profession, he always studies, he sighs, he is anxious about the desire he has of perfection, and glory, and he never tires of finishing and finishing his work” (Ricconi 2012). The *pentimenti* painted by Donato Creti concern the profile, the eye, and the hands of Cleopatra (Fig.1 f, d). Also, the canvas has several stuccoes (gaps filled with stucco, Fig.1 b), made in old restorations, and several mimetic retouches, especially evident in the neck area and on the shoulder (Fig.1 e).

3. Methodology

The ROIs to be separated can be classified into three categories: pentimenti of the artist, old restoration interventions, restoration interventions carried out in 2019. Our purpose is to highlight and separate the different regions through image analysis.

3.1. Image dataset

The input image dataset has been captured in different modalities: under visible light illumination, with two Nitraphot 500W diffuse-light projectors and a Macbeth Color Checker used as the reference, an RGB image was captured by a Nikon D800 camera. An infrared image (IR) at 1050 nm (Fig.2b), with a high dynamic range (16 bits), has been acquired through a multispectral system based on Morovian G2-8300 (CCD KAF 8300 18.1 × 13.7 mm pixels 5,4 × 5,4 μm). The sensor is cooled to reduce the electronic noise during acquisition. The spectral resolution is obtained through interferential filters with ± 25 nm passbands around the

central wavelengths 450, 500, 550, 600, and 650 nm in the visible range and 850, 950, and 1050 nm in the near-infrared. This choice ensures complete and continuous coverage of the visible range plus three infrared channels.

3.2. Image analysis through blind source separation

A painting can be seen as the combination of M different spectral components, namely, the colors of the pigments and other materials used to produce the original painting and the restoration interventions. These M spectral components represent the hyperspectral input data cube. Each of the M image channels shows a combination of the emissivities of the different materials at a given waveband. The simplest model to describe this combination is the linear, instantaneous one (Hyvärinen et al. 2001)

$$x(t) = As(t), t = 1, 2, \dots, L \quad (1)$$

where t is a pixel index, and L is the number of pixels in the input image, x is an M -vector representing the spectral samples captured at each pixel, s is an N -vector quantifying the presence of the different components at each pixel, and A is an $N \times M$ mixing matrix whose element a_{ij} represents the emissivity of component j at the i -th band. In this scenario, if we are able to extract vector s from the observed vector x , we can estimate the N individual component maps. Since we assume that each region of interest has an approximately uniform spectral appearance, the N estimated component maps could be inspected visually

to locate the regions of interest. Usually, we know neither the total number N of components nor the emissivity spectra A . The techniques used to estimate s from x alone are called of *blind* source separation - BSS (Cardoso 1998) since they solve system (1) with no knowledge of matrix A . Some additional assumption must replace this missing knowledge. By the Independent Component Analysis (ICA) principle (Hyvärinen et al. 2001), if A is a tall, full-rank matrix and the components are independent and non-gaussian, a copy of vector s can be estimated from x . Other approaches, such as Principal Component Analysis (PCA) and symmetric whitening (SW, see Cichocki et al. 2002, Tonazzini et al. 2007), in some cases, produce equally useful results by simply assuming uncorrelation between the components. Thus, if the number N of spectrally discernable components in the images is not larger than M , we can solve the BSS problem by ICA or PCA. If the components are more than the image's channels (M), some of the output channels will still contain mixtures of different components, possibly preventing the ROIs from being recognized. This is a very likely situation because each artwork presents many different components related to materials and techniques used in her conservative history, which are not always simple to separate spectrally.

For this reason, we often have different components mixed in the same output channel. In this situation, the only solution that has proved to be useful is the restorer's inescapable judgment. Indeed, it is always necessary to inspect the outputs channels to choose the ones that better highlight specific components in regions of interest (ROIs). Due to the impending judgment of the restorer, our methodology is defined as semi-automatic. The automatism is present in the segmentation of the N separated components, the extraction of the binary mask and the raster-to-vector conversion of the highlighted areas. The recognition and classification of the components are always up to the judgment of the restorer. In this case study of the methodology helped the restorer to locate the ROI and extract them from the image domain. We assume the nine channels in Fig. 2 as our input data and apply the three processing strategies mentioned above, each assuming 9 components, thus obtaining 27 output images, from which we try to locate the regions of interest related to the artist's *pentimenti*, to the old restoration, and to the 2019 restoration. Figure 3 reports the three output channels chosen, all resulting from the application of an ICA algorithm called FastICA (Hyvärinen et al. 2000), from which the three regions of interest can easily be recognized by the restorer and extracted by any existing thresholding algorithm.



Fig.2 Cleopatra by Donato Creti. A representative set of multispectral image capture by Vincenzo Palleschi.

3.3. Self-organizing map segmentation

The Kohonen self-organizing map (SOM) is a particular kind of neural network based on competitive training algorithms (Kohonen 1998) (Rumelhart et al. 1985). Its advantage over other neural networks is the capability to preserve the topological properties of the input images (Uriarte et al. 2005) (Yeo 2005). SOMs have long been used to segment different types of images due to their characteristic of learning to respond in the same way to the same inputs (Kon et al. 1995). In this work, the SOM neural network has been applied, using as inputs the output images of the statistical preprocessing performed through ICA, PCA, and SW, with the intention of testing whether we can obtain a further improvement in ROI extraction. In the worst case, we can get output maps similar to the inputs; in the best case, we can get outputs in which different ROIs appear in different maps. The SOM outputs are binary maps, thus, besides improving the segmentation, they can also allow for a straightforward production of the contours of both the ROIs and the represented figures, without the need of applying any threshold. In figure 4, we show some examples of the results.



Fig.3 Some output channels of the FastICA algorithm from the multispectral set input. (a) Channel 1: here, the darkest regions correspond to the pictorial reintegration performed in 2019, especially in the face and shoulder. (b) Channel 3: the darkest regions in this ICA output correspond to the old pictorial reintegration. These regions are particularly visible on the profile of the forehead, nose and neck, the hand, and the red tunic. The numerous gaps also correspond to very dark pixels. (c) Channel 4: This output contains much information on the different restoration works; the gray levels represent the thickness of the color used. Black represents a dense color layer of color, whereas progressively light gray levels represent thinner color layers.

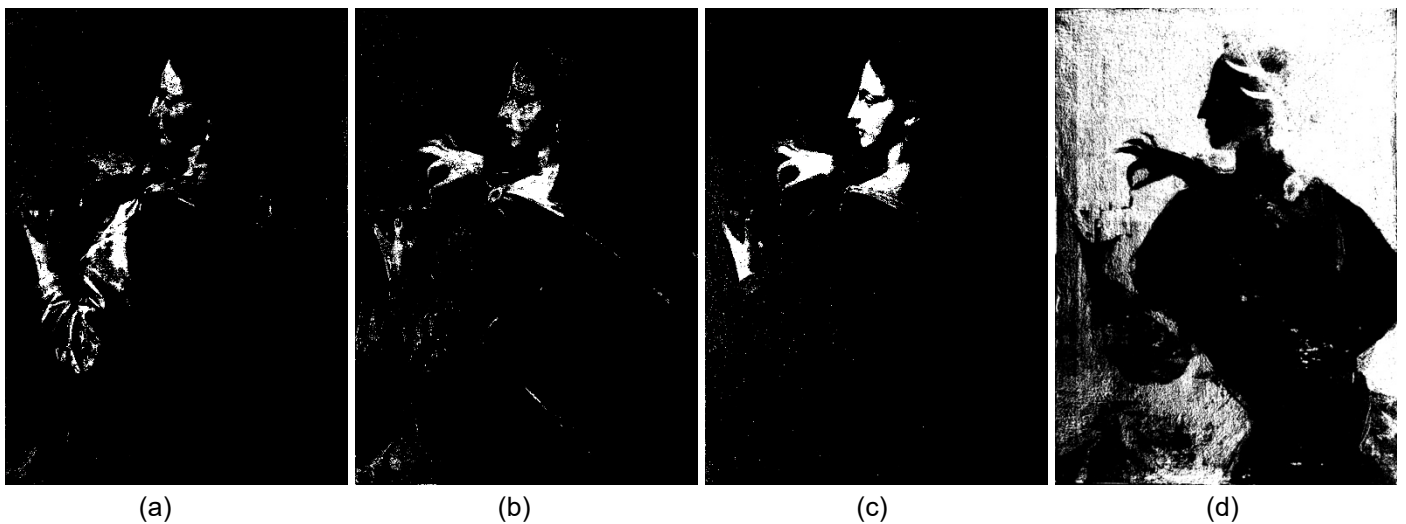


Fig.4 Some SOM outputs with FastICA and PCA inputs. (a)(b) SOM output from FastICA: These two binary masks classify the different restoration interventions and the different types of a mixture of white pigments; (c) (d) SOM output from PCA: contours of the figure. This image was used to draw the Model of the Artwork in thematic maps.

4. Results: feature extraction, vectorization, and final graphic documentation

After visually analyzed the outputs of all the elaborations, the restorer chooses those where the regions appear more clearly. In our case, we have manually drawn only the *Artwork Model*, helping ourselves, when possible, with the raster to vector conversion of the SOM outputs, which in some cases delineate the edges of the figure with high precision. Two *Artwork Models* have been created: the first, from the RGB image (Fig.3 a), it is the outline of the painting in its current state; the second, from the 1050 nm channel (Fig.3 b) and the Output SOM from PCA (Fig. 4 d), is the outline of the earliest version of the artwork. Overlapping these two drawings is possible to see the difference between the two versions and the artist's *pentimenti* (Fig.5 c). Instead, the *Information Model* (Fig. 4) was exclusively created with automatic procedures, starting from the three outputs of FastICA (channels 1, 3 and 4), with an automatic raster to vector conversion of the region of the areas identified, resulting into the extraction of edges and areas of the regions of interest ROIs. Each channel was processed individually through the different values of threshold, thus obtaining various binary masks. The extraction can be performed in two ways, both present in many commercial tools: by thresholding or by selecting the value of the pixel of interest through slicing algorithms (Mabrouk 2013). Each channel was processed individually through the different values of threshold, thus obtaining various binary masks. An enhancement step is essential here

because the FastICA outputs contain backgrounds of different intensity, and this might confuse. A morphological filtering algorithm has been applied to the areas of FastICA to reduce noise and maintain linear edges (Zhao 2008). Subsequently, two vector drawings have been created through raster to vector conversion. All the operations used can be performed through different software tools. In our case, we used MatLab for image analysis (ICA, PCA, SW, SOM) and QGIS 3.6 for thresholding, raster to vector conversion, classification, and characterization of the ROIs, and to set the graphic relief (*thematic maps*). It is essential to specify that the polygons extracted with this method can be read by other commercial tools widely used in the documentation for cultural heritage, such as AutoCAD and SICAR.

5. Conclusion

The present work describes the first steps towards the development of an integrated methodology that uses new digital technologies to support graphical documentation in Cultural Heritage. Algorithms of image segmentation and neural networks have never been used in this field, and our work demonstrates their potentiality in reducing subjectivity and speeding up the entire process. However, it is necessary to specify that the final result depends on the type of artwork and the quality of images used as input to these methods. In this respect, it is possible to create a guiding model and give

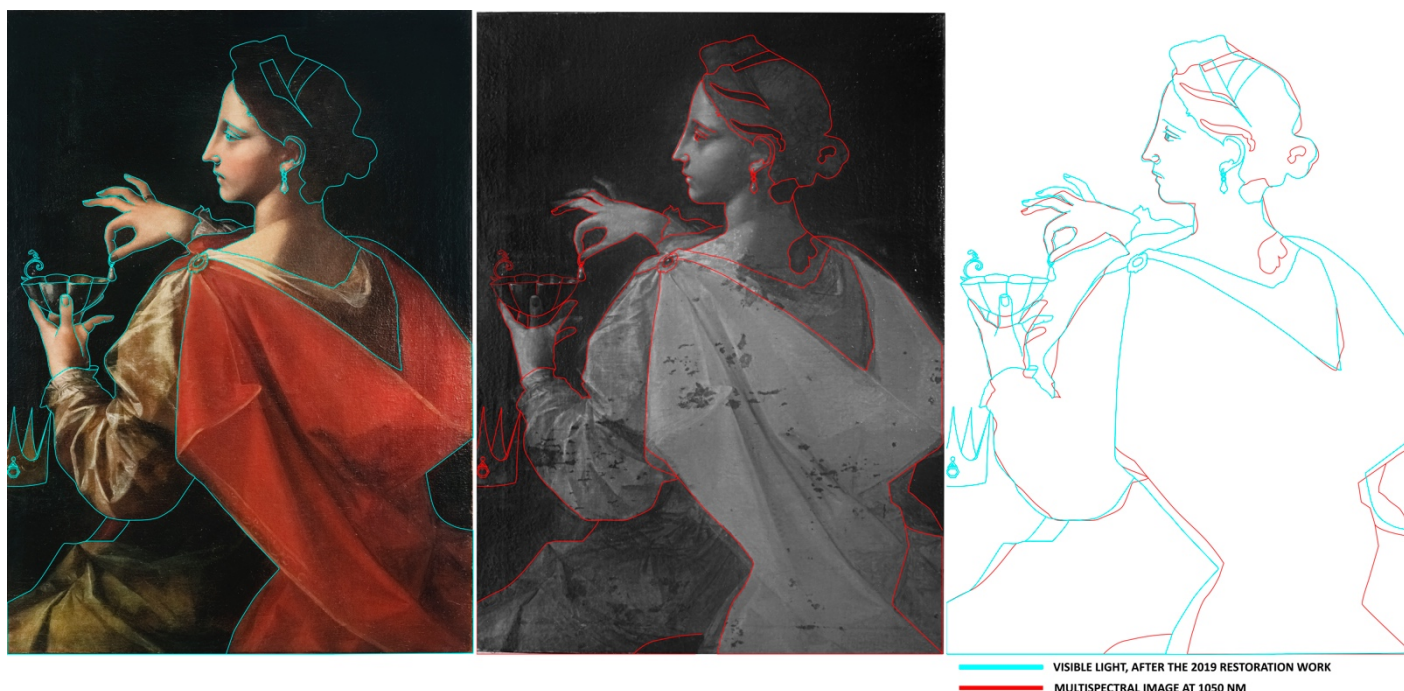


Fig.5 Two Artwork Models (a) image in visual range RGB, the final version of the figure, (b) First version of the figure visible in the multispectral image at 1050 nm. (c) Overlap of two Models, the difference between the first version and the final version with the pictorial *pentimenti* executed by the artist.

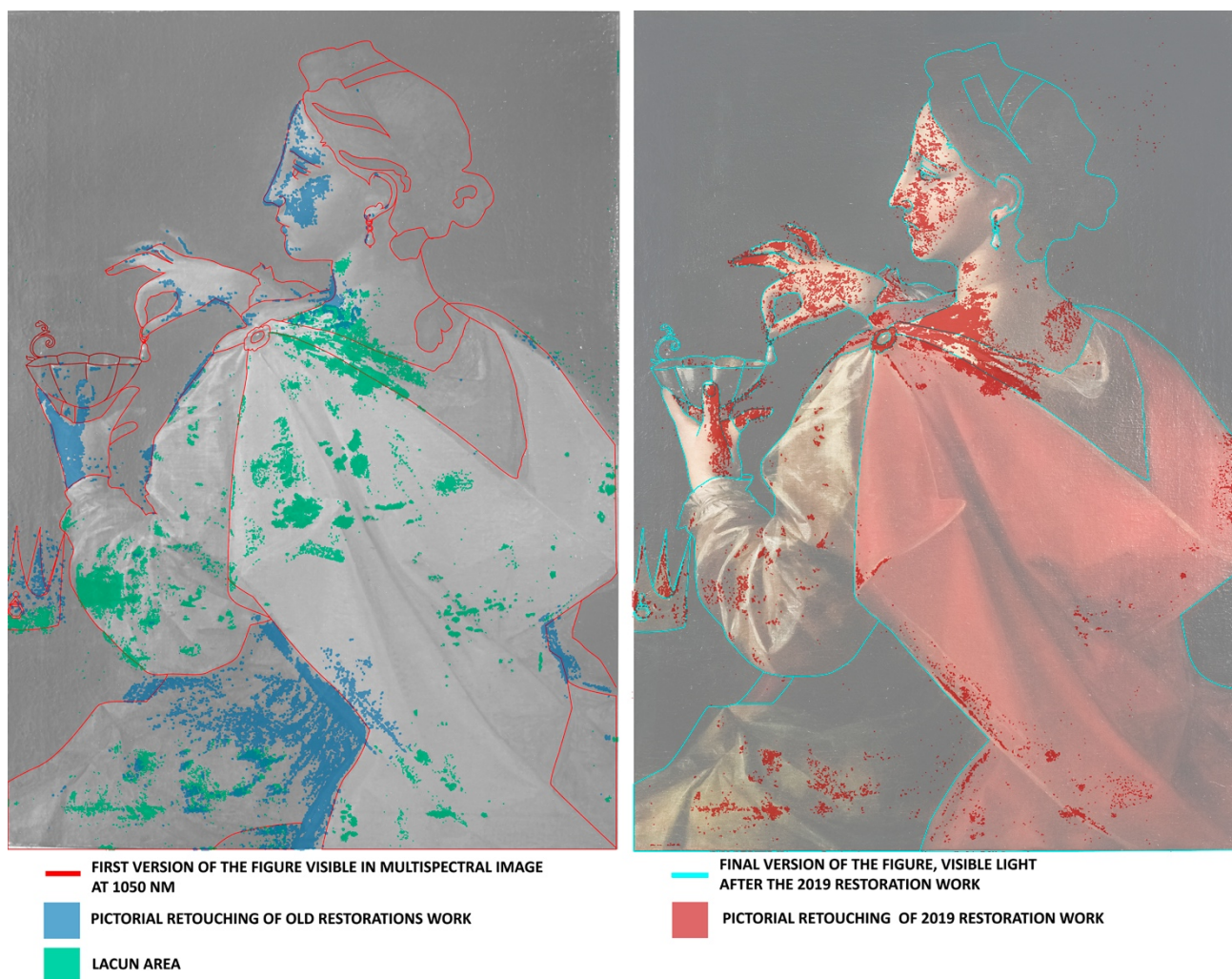


Fig.6 The two thematic maps obtained from the automatic extraction of the regions of interest from the raster outputs of the ICA are shown. For each information, a specific color has been assigned.

specific indications on the quality of the images to be used. For example, high resolution and limited noise and light reflections could be required. In this case study, the methodology has integrated and supported the planning process of restoration intervention, we have identified three distinct moments in the history of our case-study artwork and have been able to map and document the results much more quickly and accurately than any current manual graphic documentation. We are planning to implement this methodology in open-source GIS software to combine all operations into an easy tool for restorers. Moreover, implementing this methodology in a GIS system allows us to obtain a quantitative evaluation of the surface degradation, by applying the zonal statistical analysis tools to the polygons representing the ROIs.

6. Conflict of interest declaration

The authors declare that nothing affected their objectivity or independence and original work. Therefore, no conflict of interest exists.

7. Funding source declaration

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9. A short biography of the authors

Annamaria Amura is a Ph.D. Candidate in Computer Science at the University of Urbino. She holds a BS degree in Technology for the Conservation and Restoration of Cultural Heritage, Class 41, and an M.Sc. degree 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, and graphic documentation.

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Stefano Pagnotta Dr. Pagnotta is an editorial board member of the Anthropology Open Journal and "Cultore della Materia" in Archaeology at the University of Pisa. Ph.D. in Earth Sciences, Md in Archaeology and Bd in Conservation of Cultural Heritage. Actually, he is a research fellow at ICCOM CNR. Visiting scientist at the Institut für Chemie in Potsdam, at the Pure and the Applied Science Department University of Urbino and the Vinča Nuclear Institute. Author of more than 50 papers in international peer-reviewed journals.

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Notes

[1] *Pentimenti* is an Italian term that identifies the painting modification performed by the same author during the creation of the painting.

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La Cleopatra di Donato Creti

acquisizioni multispettrali
e indagini diagnostiche

Cleopatra di Donato Creti

Restauro

a cura di Lucia Palma

Acquisizioni multispettrali e indagini XRF

a cura di Vincenzo Palleschi e Stefano Pagnotta,
Istituto di Chimica dei Composti Organometallici
Consiglio Nazionale delle Ricerche (CNR) di Pisa.

Fotografie in luce visibile

Progetto di ricerca

Impaginazione grafica

a cura di Amura Annamaria

dottoranda

Dipartimento di scienze di Base e Applicazioni

Università degli studi di Urbino Carlo Bo.

Intervento di Restauro

Stato conservativo dell'opera pre restauro

Il dipinto olio su tela era arrivato in condizioni conservative piuttosto precarie. L'opera aveva subito negli anni diversi interventi di restauro; era stata foderata, pulita e ritoccata. Dopo diversi anni dall'ultimo intervento, sulla superficie pittorica erano comparsi numerosi sollevamenti e microsollevamenti, cadute di pellicola pittorica, soprattutto sulla parte bassa, dovute forse a sbalzi termogrometrici troppo forti, compromettendo seriamente l'opera. Lo strato pittorico stava in condizioni conservative mediocri, in alcuni punti era stato ritoccato in maniera molto pesante ed era alterato nelle sue cromie. La superficie era interessata da un'insieme di vecchi sporchi depositatisi negli anni e da ingiallimento della vernice.

L'intervento

L'intervento di restauro è stato progettato per bloccare il processo di degrado e riavere una corretta leggibilità ed è stato effettuato eseguendo le seguenti operazioni:

- Fissaggio della superficie pittorica tramite iniezioni di collanti in presenza di vistosi sollevamenti della pellicola e della preparazione.
- Pulitura sommaria della superficie pittorica tramite l'applicazione di leggere miscele solventi con tamponi di cotone idrofilo e mezzi meccanici quali bisturi e pennelli morbidi da spolvero.
- Pulitura definitiva del colore previ saggi per verificare i diversi strati di polvere sporco e di vecchie vernici applicate nel corso di precedenti interventi, al fine di accertare l'idoneità dei solventi e i relativi dosaggi.
- Rimozione del suddetto sporco tramite stesura diretta o in emulsione di solventi volatili appositamente studiati.
- Stuccatura delle lacune, rasature delle stesse con intervento meccanico a bisturi per eliminare lo stucco debordante sulla superficie originale, pulitura dei bordi. Livellatura delle superfici stuccate e preparazione materica onde eguagliarla alla materia originale circostante.
- Reintegrazione pittorica delle stuccature con colore a tempera, come base preparatoria per il restauro pittorico, seguita da successiva stesura di colore a vernice per accompagnare cromaticamente le mancanze.
- Verniciatura finale della superficie pittorica eseguita come protezione finale del dipinto. Stesura a pennello e successivamente a spruzzo ripetuta per fasi fino all'assorbimento omogeneo della superficie.

Durante i primi saggi di pulitura sono emersi degli interessanti ripensamenti e ridinture. Sono stati quindi coinvolti i diagnostici del CNR di Pisa per poter effettuare le indagini di *imaging* utili alla piena comprensione dell'opera e alle scelte dell'intervento.



Saggi di pulitura per la rimozione dello sporco superficiale e della vernice ingiallita.



Ripensamenti dell'artista sul volto e pesanti ritocchi pittorici presenti sulla spalla



Ripensamenti dell'artista sulla posizione della mano e delle dita



Intervento di stuccatura effettuato sulle lacune e sulla rimozione delle ridipinture.

Indagini XRF

Strumenti e metodi

Il dipinto è stato analizzato utilizzando la tecnica della Fluorescenza a Raggi X (X-Ray Fluorescence = XRF). Con questa tecnica è possibile fornire in maniera molto rapida una stima della composizione elementare della pellicola pittorica in esame senza produrre alcun danno su di essa. Lo strumento impiegato per l'analisi è lo spettrometro XRF a dispersione di energia prodotto dalla XGLab (Milano); per le misure sui campioni è stata utilizzata un'energia del tubo di 40 kV, con una corrente di 60 μ A (3.2 W) e un tempo di acquisizione di un minuto a campione. Il tubo a raggi X ha un anodo in Rodio.

Lo spettrometro utilizza un rivelatore di raggi X di tipo Silicon Drift di grandi dimensioni (25mm²), con una risoluzione in energia di 130 eV a 6 KeV.



Nella analisi dei dipinti la fluorescenza di raggi X (XRF) costituisce uno standard per la comprensione della composizione elementare della pellicola pittorica. Generalmente è accoppiata ad altre tecniche come l'imaging multispettrale per poter comprendere a cosa sono dovute le differenze tra pigmenti che ad occhio appaiono simili ma composizionalmente sono differenti. Nel caso dei dipinti l'analisi è puramente qualitativa: serve a determinare unicamente la presenza di un elemento chimico piuttosto che un altro.

Utilizzando le informazioni ottenute con l'indagine XRF e con l'imaging e confrontando i dati con un compendio sull'utilizzo dei pigmenti nella storia dell'arte possiamo determinare se il pigmento ipoteticamente individuato dalle indagini è coerente o meno con l'opera in esame.

Punti analizzati

Individuazione dei punti di misura effettuati con lo strumento XRF.



Tabella 1

Individuazione degli elementi presenti nei punti analizzati (Analisi XRF).
In grassetto e sottolineato l'elemento che presenta il picco di intensità maggiore.
Tenere sempre presente che si tratta di una analisi puramente qualitativa.

Punto	Colore	Elementi individuati
P1	Bianco/verde	<u>Pb</u> , Fe, Ca, S, Ti, Sb, Cr, Mn, Zn
P2	Verde	<u>Pb</u> , Fe, Ca, S, Mn, Ti,
P3	Rosso	<u>Hg</u> , Pb, Fe, Mn, S, Ca
P4	<u>Arancione</u>	<u>Hg</u> , Pb, Fe, Mn, S, Ca
P5	<u>Ombra mantello</u>	Pb, <u>Fe</u> , Mn, S, Ca, Hg
P6	Rosso	<u>Hg</u> , Pb, Fe, Mn, S, Ca
P7	Giallo	Pb, <u>Fe</u> , Mn, Ca, S,
P8	Rosso	Pb, <u>Fe</u> , Mn, Ca, S,
P9	Bianco/rosa	<u>Pb</u> , Ca, S, Ti, Fe, Mn, Hg (tr.)
P10	Rosa	<u>Pb</u> , Fe, Mn, Ca, S, Ti
P11	Rosa scuro	<u>Pb</u> , Fe, Mn, Ca, S, Ti, Cr
P12	Grigio	<u>Pb</u> , Fe, Mn, Ca, S, Ti (tr.)
P13	Giallo	<u>Pb</u> , Fe, Mn, Ca, S, Ti (tr.)
P14	Bianco	<u>Pb</u> , Ca, S, Ti, Fe, Mn.
P15	Rosso/Giallo	<u>Pb</u> , Mn, Fe, Ca, S,
P16	Verde (?)	<u>Pb</u> , Fe, S, Mn, Ca, <u>Ti</u>
P17	Bianco/rosa	<u>Pb</u> , Ca, S, Ti, Fe, Mn, Hg (tr.)
P18	Rosa	<u>Pb</u> , Ca, S, Ti, Fe, Mn, Zn, Hg (tr.)
P19	Bruno	Pb, <u>Fe</u> , Mn, S, Ca, Hg

P1

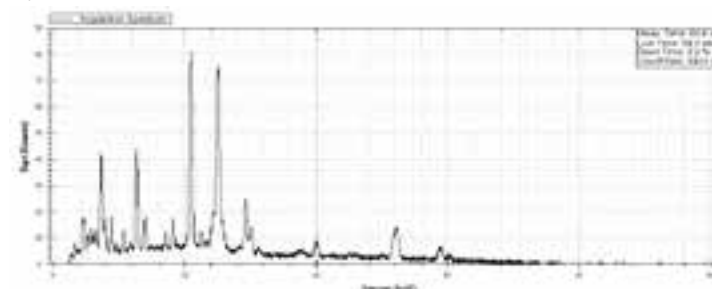
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XGLAB
X-ray and Gamma-ray Laboratory

Measurement Time: 60.0 s
Tube Voltage: 40 kV
Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element

Analysis Date and Time: NA
Analysis Type: Automatic
Spectrum Left Cut: 0 keV
Spectrum Right Cut: 0 keV
Spectrum Upper Limit: 0 keV
Use M Line: False
Super Impose Peak Areas: False

P2

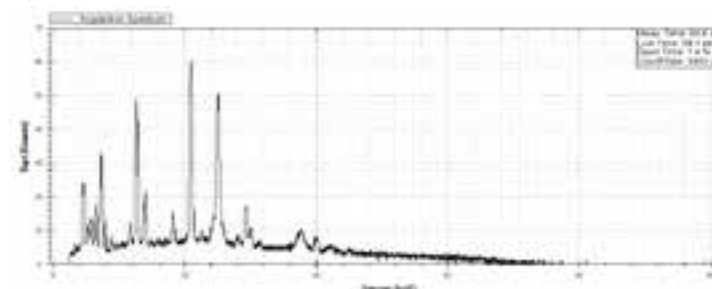
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XGLAB
X-ray and Gamma-ray Laboratory

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Tube Voltage: 40 kV
Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element

Analysis Date and Time: NA
Analysis Type: Automatic
Spectrum Left Cut: 0 keV
Spectrum Right Cut: 0 keV
Spectrum Upper Limit: 0 keV
Use M Line: False
Super Impose Peak Areas: False

P3

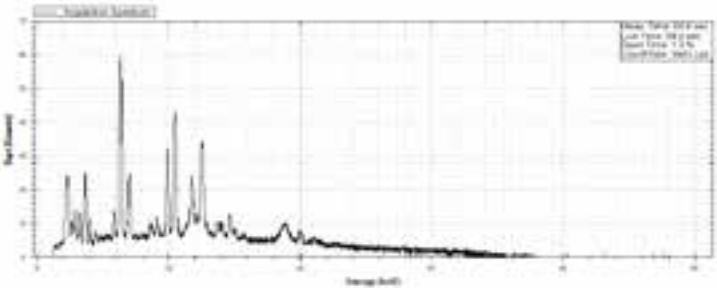
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Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P4

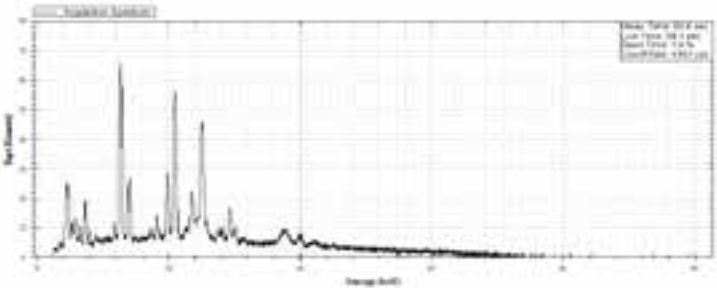
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Measurement Time: 60.0 s
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Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P5

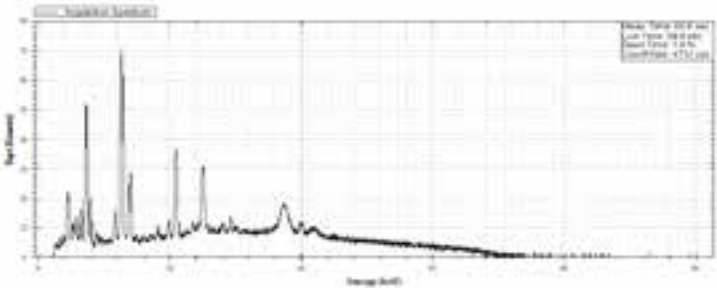
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Measurement Time: 60.0 s
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Tube Current: 60 µA
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Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P6

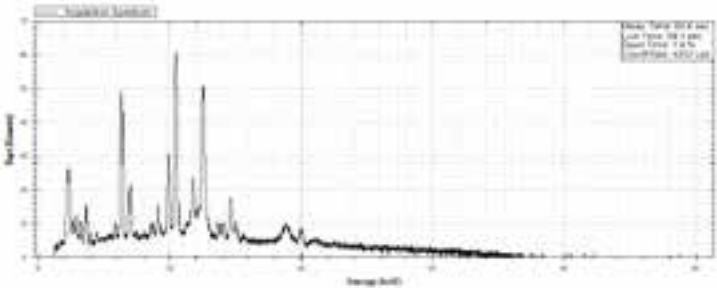
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Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
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Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P7

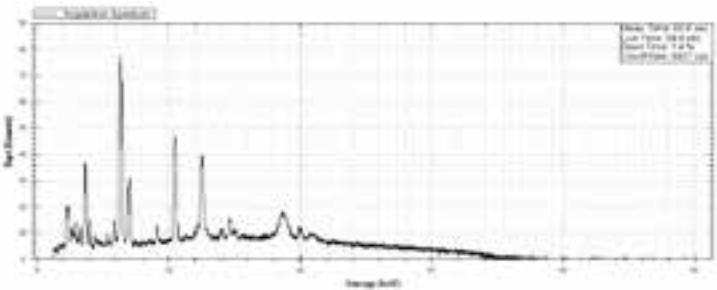
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Measurement Time: 60.0 s
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Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

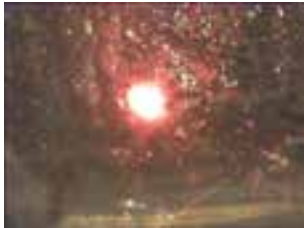
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Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P8

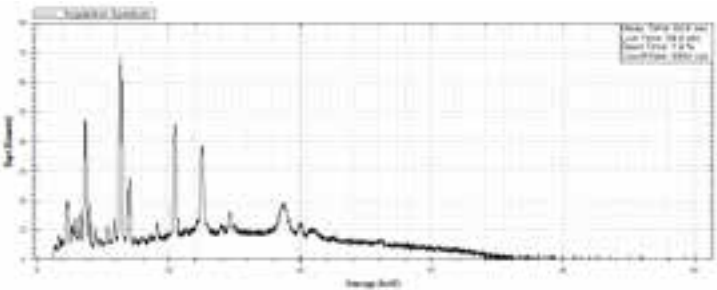
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Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P9

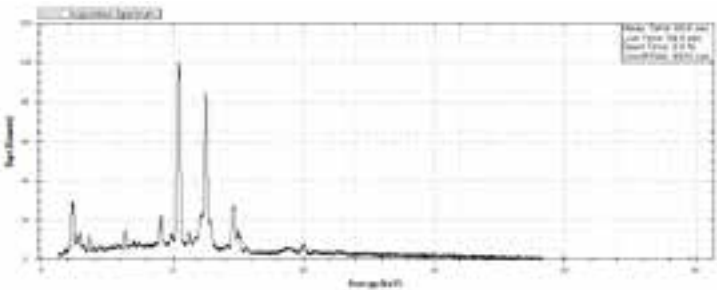
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Measurement Time: 60.0 s
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Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
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Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P10

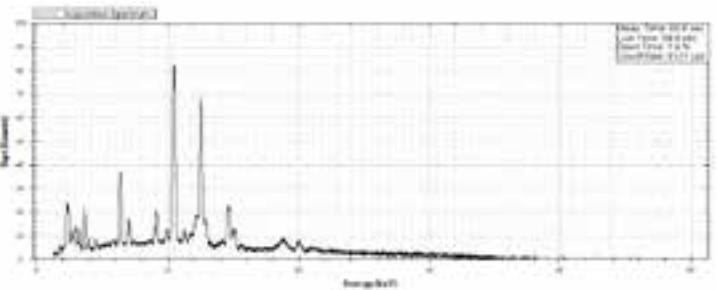
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Measurement Time: 60.0 s
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Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
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Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P11

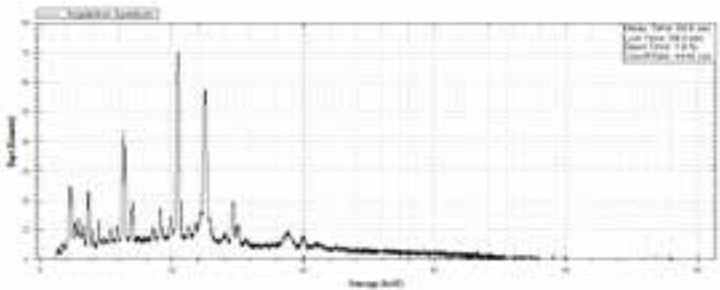
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Measurement Time: 60.0 s
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Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time:	NA
Analysis Type:	Automatic
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Spectrum Right Cut:	0 keV
Spectrum Upper Limit:	0 keV
Use M Line:	False
Super Impose Peak Areas:	False

P12

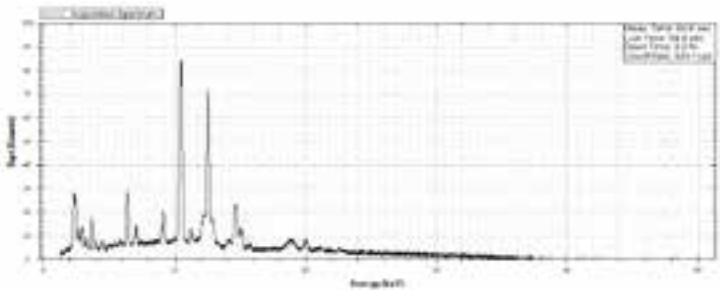
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Measurement Time: 60.0 s
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Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

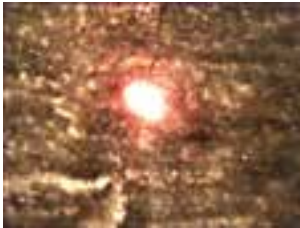
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Super Impose Peak Areas:	False

P13

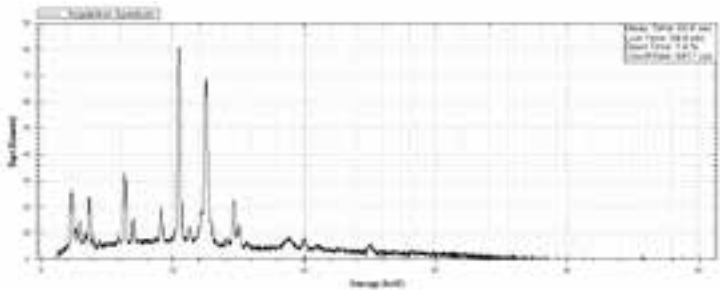
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Measurement Time: 60.0 s
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Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time:	NA
Analysis Type:	Automatic
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Spectrum Right Cut:	0 keV
Spectrum Upper Limit:	0 keV
Use M Line:	False
Super Impose Peak Areas:	False

P14

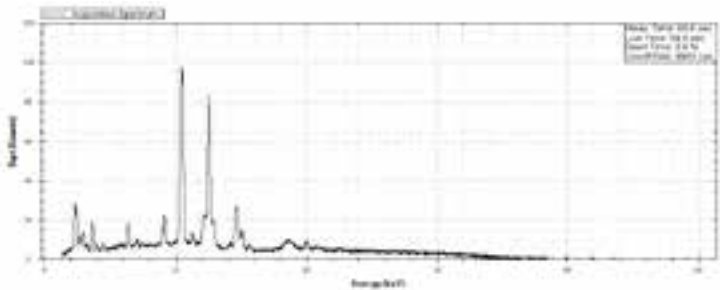
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Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time:	NA
Analysis Type:	Automatic
Spectrum Left Cut:	0 keV
Spectrum Right Cut:	0 keV
Spectrum Upper Limit:	0 keV
Use M Line:	False
Super Impose Peak Areas:	False

P15

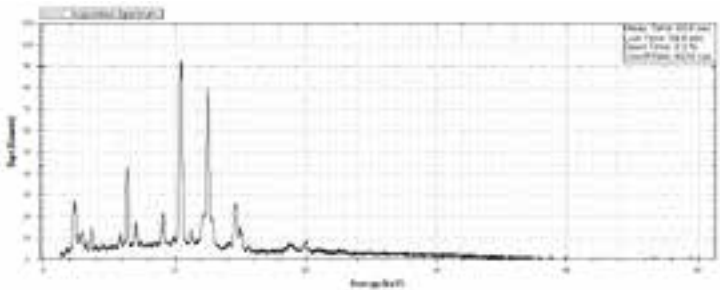
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Measurement Time: 60.0 s
Tube Voltage: 40 kV
Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P16

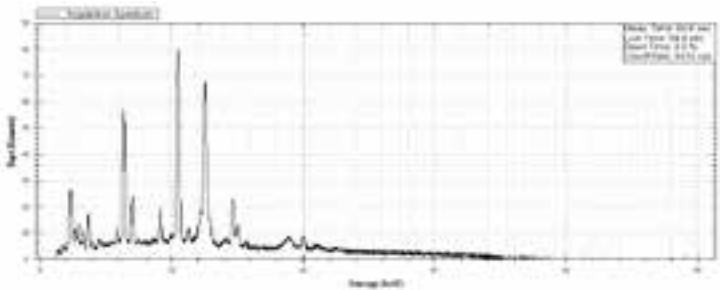
04/04/2019 15:04:44



Measurement Time: 60.0 s
Tube Voltage: 40 kV
Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P17

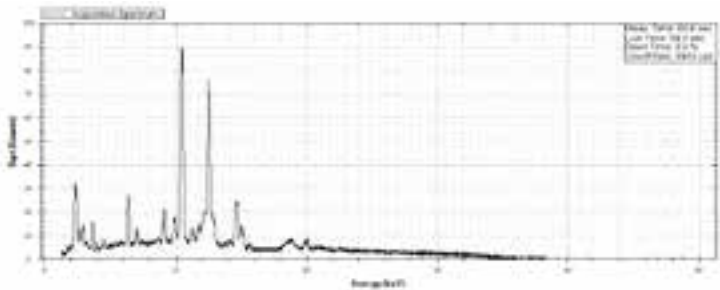
04/04/2019 15:07:32



Measurement Time: 60.0 s
Tube Voltage: 40 kV
Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P18

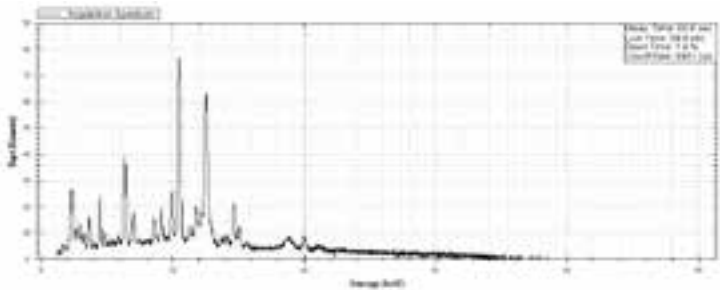
04/04/2019 15:09:40



Measurement Time: 60.0 s
Tube Voltage: 40 kV
Tube Current: 60 µA
Tube Target Material: Rh
Elio Device: SN604
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element	
Analysis Date and Time: NA	
Analysis Type: Automatic	
Spectrum Left Cut: 0 keV	
Spectrum Right Cut: 0 keV	
Spectrum Upper Limit: 0 keV	
Use M Line: False	
Super Impose Peak Areas: False	

P19

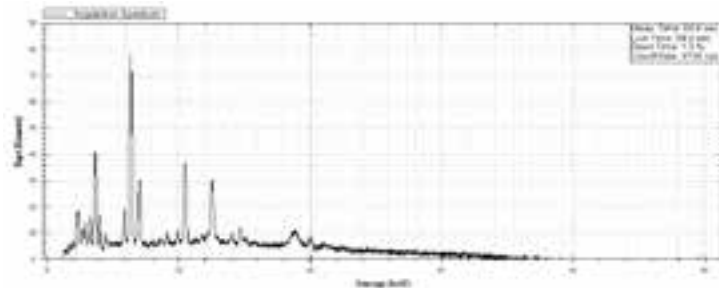
04/04/2019 15:15:12

XG
LAB
X-ray and Gamma-ray Analysis

Measurement Time: 60.0 s
 Tube Voltage: 40 kV
 Tube Current: 60 μ A
 Tube Target Material: Rh
 Elio Device: SN604
 Device Mode: Head
 Acquisition Mode: Manual
 Acquisition Channels: 4096
 Sample to Detector Material: Air



Spectrum:



Analysis Results:

Element

Analysis Date and Time: NA
 Analysis Type: Automatic
 Spectrum Left Cut: 0 keV
 Spectrum Right Cut: 0 keV
 Spectrum Upper Limit: 0 keV
 Use M Line: False
 Super Impose Peak Areas: False

Riprese Multispettrali

Strumenti e metodi

La ripresa ad infrarossi (IR) è stata effettuata con un intervallo dinamico elevato (16 bit), attraverso un sistema multispettrale con una camera Morovian G2-8300 (CCD KAF 8300 $18,1 \times 13,7$ mm pixel $5,4 \times 5,4$ μ m).

La risoluzione spettrale si è ottenuta attraverso filtri interferenziali con bande passive di ± 25 nm attorno alle lunghezze d'onda centrali 450, 500, 550, 600 e 650 nm nel campo visibile e 850, 950, 1050 nm nel vicino infrarosso.

