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Mid-wave infrared imaging analysis of XVII century paintings on canvas of the Chigi Palace in Ariccia

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***Abstract* – In this work, mid-wave infrared (MWIR) imaging techniques are applied to the study of three XVII century paintings on canvas preserved at the Chigi Palace in Ariccia. In particular, an integrated approach based on the use of pulsed thermography (PT) and MWIR reflectography (MIRR) is proposed for the analysis of the "Primavera" by Filippo Lauri e Mario Nuzzi, the "Ritratto di Mario Nuzzi che dipinge un vaso di fiori" by Giovanni Maria Morandi and Mario Nuzzi and the "Ebbrezza di Noè" by Andrea Sacchi. It is shown how the combined use of these techniques enables to perform the depth-resolved characterization of the analysed paintings, revealing complementary information on both subsurface graphical features, such as *pentimenti*, and structural elements.**

I. INTRODUCTION

In the study of painted artefacts, precious information for scholars can be obtained by displaying features lying beneath the surface pictorial layers, such as underdrawings and *pentimenti*. Since this kind of information is often not accessible by the naked eye, non-destructive techniques for the inspection of the inner part of artworks are required [1]. For these purposes, optical methods based on the use of infrared (IR) radiation are nowadays considered effective tools for the analysis of subsurface features in Cultural Heritage (CH). Among these methods, infrared reflectography (IRR) is the most adopted technique, mainly employing the near infrared (NIR) range.

In particular, NIR reflectography (NIRR) provides information about the very first layers beneath the painted one [2], thus allowing one to detect underdrawings and subsurface elements by the use of several types of imaging devices [3]–[6]. All these approaches explore the same stratigraphic layer, recording IR images with an increasing level of detail and, consequentially, costs [7].

Nevertheless, most of the interesting underlying elements on an artefact with a stratigraphic structure are often beneath multiple layers of painting and materials. The use of the mid-wave infrared (MWIR) range (3-5 μm) in imaging analyses make it possible to increase the depth of non-destructive investigation and, consequentially, to reach integrative and complementary information with the respect to those achievable with the only NIR techniques, exploiting the increased penetrative power of the MWIR band within the artefact [8].

In recent years, imaging techniques operating in MWIR range have been employed on different kind of painted artefacts, such as wooden/canvas paintings [9] and illuminations [10] by using pulsed thermography (PT) and MWIR reflectography (MIRR), separately.

In particular, PT is based on the detection of the time-dependent distribution on the sample surface of the IR radiation emitted following the heating induced by the absorption of a short light pulse in the visible range (VIS). This technique proved to be able to characterize the main surface and subsurface elements of CH artefacts [11], [12], providing information on both the conservative state and subsurface graphical and pictorial features, such as underdrawings and *pentimenti* [13].

Similar items have been also investigated by using MIRR, which collects the images just after the illumination of the sample by MWIR radiation [13]. This to reduce stray effects on the reflectographic image caused by the MWIR radiation emitted because of the sample heating.

The innovative approach proposed in this work is the combined use of the two mid-wave infrared imaging techniques, usually employed separately, for obtaining stratigraphic and complementary information of the artwork by using the same device and same resolution.

Indeed, the choice of employing the same IR camera for recording both the thermograms and the reflectograms allows to gain images with the same framing and pixel-resolution, giving an immediate and accurate visualisation of the two type of information without the need of rescaling/rotating each image.

Furthermore, the correspondence pixel-by-pixel of the

thermographic and reflectographic images makes it possible to better highlight relevant features detected by one technique and exclude the less important ones revealed by the other, even by an eventual combined processing of the two kind of images.
In the framework of the project ADAMO [14], this integrated use of PT and MIRR has been adopted and successfully tested to stratigraphically investigate some XVII century paintings on canvas preserved at the Chigi Palace in Ariccia. In particular, the "Primavera" by Filippo Lauri e Mario Nuzzi (Mario de' Fiori), the "Ritratto di Mario Nuzzi che dipinge un vaso di fiori" by Giovanni Maria Morandi and Mario Nuzzi and the "Ebbrezza di Noè" by Andrea Sacchi are analysed for the first time by using MWIR imaging techniques in order to detect subsurface features, such as *pentimenti*, and structural elements.

II.THE XVII CENTURY PAINTINGS OF PALAZZO CHIGI IN ARICCIA

The "Primavera" (Fig. 1) by Filippo Lauri and Mario Nuzzi is a painting on canvas belonging to the series "Le Quattro stagioni" preserved at the Ariccia's Chigi Palace. The entire painting series has been executed between the 1658 and the 1659 on a commission from Flavio Chigi and it is considered one of the greatest examples of Roman Baroque. All the figures have been painted by Filippo Lauri, while the floral decoration has been realized by Mario Nuzzi [15].

Fig. 1. Filippo Lauri and Mario Nuzzi, "La Primavera",1659, oil painting on canvas, 150×250 cm , Chigi Palace, Ariccia.

The "Ritratto di Mario Nuzzi che dipinge un vaso di fiori" (Fig. 2) is another four-handed painting on canvas where Mario Nuzzi and Giovanni Maria Morandi realized the floral decoration and the Nuzzi portrait, respectively. In this panting, which is the latest commissioned by Flavio Chigi, Mario Nuzzi reached the highest quality level in representing a single vase flower composition [16].

Fig. 2. Giovanni Maria Morandi and Mario Nuzzi, "Ritratto di Mario Nuzzi che dipinge un vaso di fiori",1658-1659, oil painting on canvas, 195×265 cm, Chigi Palace, Ariccia.

The "Ebbrezza di Noè" (Fig. 3) preserved at the Chigi Palace is one of the numerous replicas produced by Andrea Sacchi in the second half of the XVII century. The dating of the painting is nowadays uncertain as well as the possibility of establishing whether it is the first version or one of the many replicas [17].

Fig. 3. Andrea Sacchi, "Ebbrezza di Noè",n.d., oil painting on canvas, 150×205 cm , Chigi Palace, Ariccia.

III. METHODS

Among the MWIR imaging techniques, PT has become one of the most used method for the investigation of cultural heritage [18], [19]. It is one of the so called photothermal techniques which have been widely used for the determination of the thermal transport properties of several kind of materials [20]–[24]. PT provides a sequence of IR images, referred to as thermograms [25]. In the case of semi-transparent media, such as paintings, the contrast in the thermograms originates from differences in the local optical properties of the subsurface features with respect to those of the

surrounding material. More specifically, there are two main opto-thermal mechanisms, which enable to display the buried features.

The first mechanism occurs when the features are located at a depth in the sample smaller than the penetration depth of the heating light. In this case the different absorption properties in the visible range of the features with respect to the surroundings may result in a different local temperature rise and, hence, in a contrasted IR emission recorded in the thermograms. On the other hand, when the depth of the subsurface element is too large to be reached by the incident light, the heating of the buried features can only be associated with the heat diffusing in the sample depth. Then it will be the different local values of the IR emissivity, which will induce the contrast.

In the MIRR configuration, the images are obtained by directing onto the sample the MWIR radiation coming from a suitable source. Here, the image contrast is mainly originated from local difference in the reflection of the MWIR radiation [4]. For this reason, unlike PT, MIRR does not provide information about the depth of the detected features and its application shows some limitations in the detection of features buried beneath highly MWIR radiation diffusing layers.

The set-up employed for the analysis of the Chigi paintings is the following. In the PT configuration the sample heating has been induced by means of two 3 kW flash lamps oriented at 45° with respect to the surface of the investigated sample, delivering few ms long pulses. The emitted light from the lamps has been filtered in order to eliminate any MWIR spectral component contributions to the recorded signal originating from the reflection at the sample surface. In the MIRR technique, the sample illumination has been obtained by using a continuous wave halogen lamp positioned at about 2 m from the paintings. For both techniques, the images have been recorded by means of a Cedip JADE MWIR camera (320x240 pixel, InSb focal plane array, 30 μm pitch, 3.6-5.1 μm wavelength range, Noise Equivalent Temperature Difference (NETD) < 25 mK at 30 °C) and processed by the Altair 5.50 software.

IV. RESULTS

In the following discussion, for all the investigated areas, the thermographic results will be compared with those obtained by MIRR. For ease of comparison the thermograms are presented with an inverted grey palette so that, the hotter elements will appear darker in the images.

A. The paintings by Mario Nuzzi

In the "Primavera" by Filippo Lauri and Mario Nuzzi several *pentimenti* have been found, the main ones in the Primavera, which is the central and most important figure of the pictorial apparatus. For instance, Fig. 4a shows the photograph of the right hand of the Primavera, where the corresponding thermogram (Fig. 4b) and MWIR reflectogram (Fig. 4c) reveal both structural elements and *pentimenti*, respectively. The latter, consist of the change of position of the ring finger (see the arrow in Fig. 4c). In the thermogram of Fig. 4b the *pentimento* is not detected but it is possible to obtain information on the conservation state of the canvas support. In fact, the thermogram reveals a diffusively distributed darker (hotter) areas (some indicated by the arrows) most likely associated with restored gaps. Only some of such areas are detectable in the MIRR image, appearing light because of the locally greater reflection of the MWIR radiation.

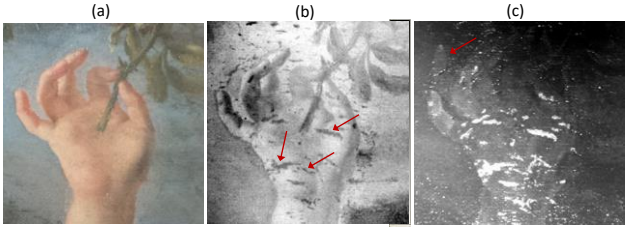

Fig. 4. The "Primavera", Filippo Lauri and Mario Nuzzi, Chigi Palace, Ariccia. (a) Photographic detail of the right hand and (b) corresponding thermogram where the arrows indicate the restored gaps; (c) MWIR reflectogram where the arrow indicates the pentimento.

Pentimenti have been detected also in the numerous cherubs. As an example, the MWIR reflectogram of Fig. 5c shows several change of minds concerning the physiognomic traits of the cherub (indicated by the arrow), which are not visible neither in the photograph of Fig. 5a nor in the thermogram of Fig. 5b. Some important information has been also obtained by PT in recovering the contrast of some darkened features, such as those concerning the cherub displayed in Fig. 6a. In this case, the MWIR reflectogram of Fig. 6c does not reveal any *pentimento*. However, the thermogram of Fig. 6b enables to display with a better contrast the facial features of the cherub, showing graphical and pictorial details lost in the picture.

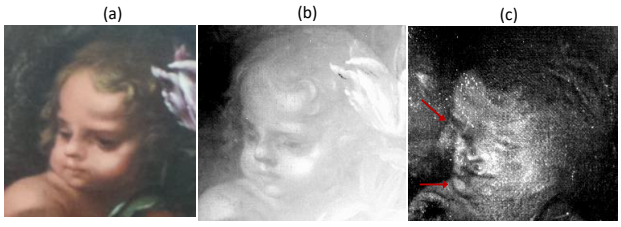

Fig. 5. The "Primavera", Filippo Lauri and Mario Nuzzi, Chigi Palace, Ariccia. (a) Photographic detail of the cherub and (b) corresponding thermogram; (c) MWIR reflectogram where the arrows indicate the pentimento.

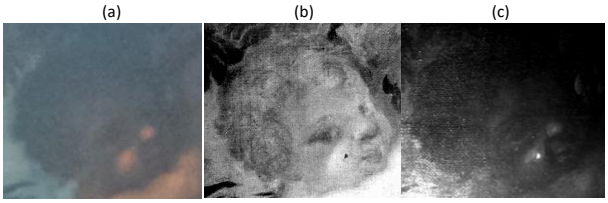

Fig. 6. The "Primavera", Filippo Lauri and Mario Nuzzi, Chigi Palace, Ariccia. (a) Photographic detail of the cherub and corresponding (b) thermogram and (c) MWIR reflectogram.

A series of *pentimenti* have also been detected in the "Ritratto di Mario Nuzzi che dipinge un vaso di fiori" by Giovanni Maria Morandi and Mario Nuzzi. As an example, both the thermogram (Fig. 7b) and the MWIR reflectogram (Fig. 7c) reveal several changes made in the head of Mario Nuzzi (Fig. 7a). The arrows in both cases indicate a different hairstyle of the first version with respect to the current appearance of the painting.

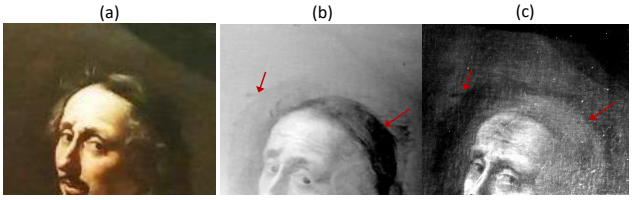

Fig. 7. The "Ritratto di Mario Nuzzi che dipinge un vaso di fiori ", Giovanni Maria Morandi and Mario Nuzzi, Chigi Palace, Ariccia. (a) Photographic detail of the Nuzzi face and corresponding (b) thermogram and (c) MWIR reflectogram where the arrows indicate some variations in the Nuzzi hairstyle.

B. The "Ebbrezza di Noè" by Andrea Sacchi

Other MWIR imaging investigations have been carried out in order to characterise the "Ebbrezza di Noè" by Andrea Sacchi. In this painting, several *pentimenti* have been revealed, like, for instance, the one reported in Fig. 8. In this case, the back view of the figure (Fig. 8a) presents numerous variations, which can be observed, in the thermogram (Fig. 8b) and in the MWIR reflectogram (Fig. 8c). In both MWIR images, the arrows indicate the tracks of a facial profile bigger than the one observable in the final version.

Another *pentimento* has been observed in the Noè foot (Fig. 9a), as shown in the thermogram of Fig. 9b and in the MWIR reflectogram of Fig. 9c. Moreover, as in the other investigated paintings, the thermogram enables to obtain a series of complementary information, like for instance the presence of defects of the canvas support.

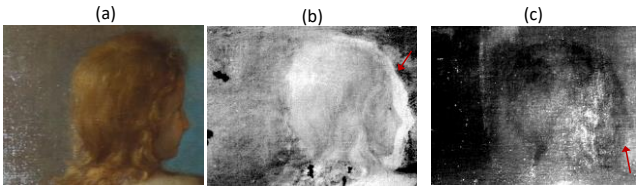

Fig. 8. The "Ebbrezza di Noè" of Andrea Sacchi, Chigi Palace, Ariccia. (a) photographic detail of the figure from the back and corresponding (b) thermogram and (c) MWIR reflectogram where the arrows indicate some changes in the facial profile.

In this case, the thermogram shows a series of dark areas (see the main one that is indicated by the blue arrow in Fig. 9b) which probably corresponds to restored gaps or filled detachments, only barely visible in the reflectogram.

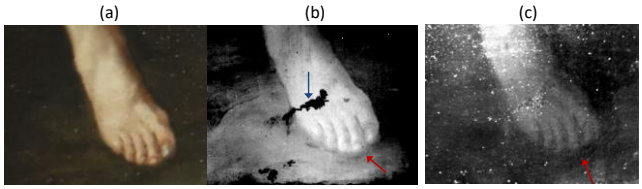

Fig. 9. The "Ebbrezza di Noè" of Andrea Sacchi, Chigi Palace, Ariccia. (a) photographic detail of Noè foot and corresponding (b) thermogram and (c) MWIR reflectogram where the red arrows indicate some changes of position. The blue arrow in the thermogram indicates one of the restored gap.

Finally, it is worth noting that for all the investigated paintings both PT and MIRR have revealed numerous information, such as the presence of *pentimenti*, relevant from the historical and artistic points of view in reconstructing the modus operandi of the artists. Moreover, it has been demonstrated how the presented combination of MWIR imaging techniques can be considered a valid tool for the detection of subsurface features which are commonly investigated only by using the traditional NIRR and x-ray radiography techniques.

V. CONCLUSION

In this work, an innovative approach based on the combined use of two mid-wave infrared imaging techniques is presented by showing the results of the study of three XVII century paintings on canvas preserved at the Chigi Palace in Ariccia.

In particular, it has been shown how pulsed thermography and MWIR reflectography can be successfully used to investigate features lying beneath the surface pictorial layer and obtain complementary information about the stratigraphy of an artwork.

Moreover, the capability of both techniques in the detection of structural elements, such as repairs or defects of the canvas supports, has been highlighted. In this context, the achieved results have enabled to obtain information useful, from the artistic point of view, in reconstructing the modus operandi of the painters.

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