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IV CONVEGNO INTERNAZIONALE E INTERDISCIPLINARE
SU IMMAGINI E IMMAGINAZIONE
4th INTERNATIONAL AND INTERDISCIPLINARY CONFERENCE
ON IMAGES AND IMAGINATION

IMG23



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HERITAGE

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su Immagini e Immaginazione

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a cura di / edited by:
Stefano Brusaporci (c)
Pamela Maiezza
Adriana Marra
Ilaria Trizio
Francesca Savini
Alessandra Tata

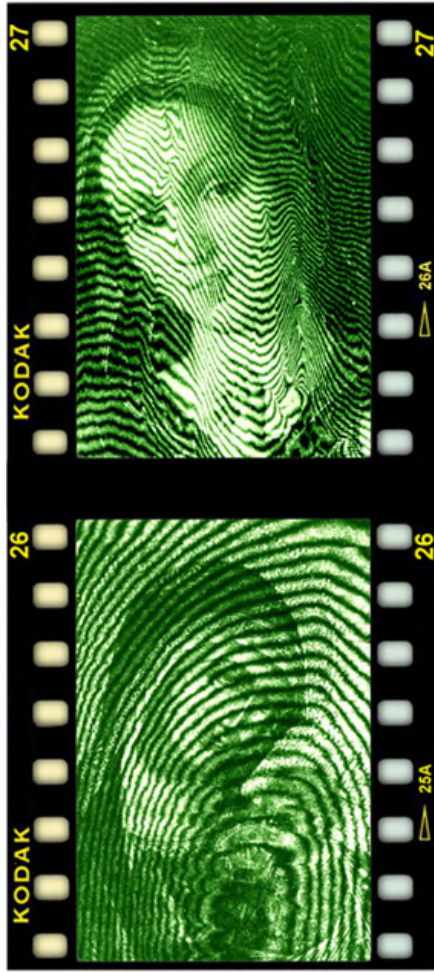
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DARIO AMBROSINI, ANNAMARIA CICCOZZI,
TULLIO DE RUBEIS, DOMENICA PAOLETTI

Optical methods: imagin(g) the hidden world of cultural heritage

Abstract

Optical methods represent a formidable tool for the preservation of cultural heritage; a large number of techniques are currently available, and the search for new methods is thriving. In this work, we will discuss some of these methods, which, in addition to providing a significant diagnostic contribution, have profoundly changed the way we engage with and imagine art.

Parole chiave

Reflectography, Holography, NDT, Thermography, Artworks.

INTRODUCTION

The preservation and restoration of cultural heritage are important tasks that require the integration of various scientific and technological approaches (Borg et al., 2020). Among these approaches, optical methods have emerged as a powerful tool for the non-destructive and non-invasive analysis of cultural artifacts (Alfeld & Broekaert, 2013). Optical methods such as holography (Amadesi et al., 1974; Paoletti & Spagnolo, 1996), electronic speckle pattern interferometry (ESPI) (Paoletti & Spagnolo, 1996; Ambrosini & Paoletti, 2004), reflectography (Ambrosini et al., 2010), optical coherence tomography (OCT) (Targowski & Iwanicka, 2012) and many others have revolutionized the field of cultural heritage by providing insights into the composition, structure, and properties of various materials.

Although the contribution of optical methods to the preservation and restoration of cultural heritage cannot be underestimated in any way, in this article we would also like to emphasise the cultural importance that the use of optical methods has had in the field of works of art. Indeed, this intersection between art, science and technology has proved to be vital and instrumental to a better understanding of the past, providing us with a window to see things in a different and deeper way. In what follows, among the many optical methods available today, we will discuss some that, due to the fact that they provide their results in the form of an image, are most suitable for comparison with the work itself and are, at least in part, easily appreciated also by the general public.

THE BEGINNING: PHOTOGRAPHY AND X-RAYS

Photography was the first revolutionary application of optical methods in the field of cultural heritage; accurate reproduction of artworks finally became possible. For many of them, which were destroyed, photographic reproduction is the only way to appreciate them now.

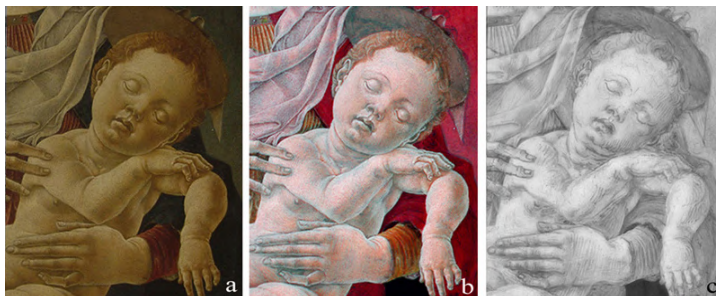
But optical methods would soon go even further, making it possible to see the hidden side of masterpieces; with X-rays, at the beginning of the 20th century, it became possible to 'see the invisible', i.e. what was hidden behind or inside works of art. X-rays could also be used for cultural heritage diagnostics, to find, for example, galleries of woodworm in panel paintings or highlight buried structures, such as nails or different materials, but they could also open a window to a different world, a world in which the artist made mistakes and changed his/her mind, erasing and moving arms and hands, faces, expressions and dresses.

The world of X-ray paintings is crowded with *pentimenti*, which is the word, full of emotional meaning, that restorers use to refer to these works of art in fieri that have remained hidden for centuries. Decades ahead of its time, X-ray diagnostics acts a bit like a modern-day text editor, where one can keep track of the errors and corrections that led the artist to the final result. In some lucky cases, the natural change in taste or the need to reuse material has led to the discovery of completely different works hidden beneath the surface.

UNVEILING THE HIDDEN ART: IR REFLECTOGRAPHY

Another major contribution to the study of cultural heritage has come from the use of infrared radiation. At first, infrared film was used with traditional cameras, which allowed the recording of radiation up to about 1.1 micron. Then, from the late 1960s, electronic devices were developed that could record infrared radiation of even greater wavelengths, up to about 2.5 micron. The technique of infrared reflectography (De Boer, 1968; Daffara et al., 2010) is now widely

Fig. 1 - Cosmè Tura, *Madonna dello Zodiaco* (detail), painting on wood, 15th century, Accademia Galleries, Venice (Italy). a) visible; b) false-color image with IR information mapped as red; c) infrared image. (Ambrosini et. al, 2011).



used. With it, it became possible to see what is beneath the paint layer. In fact, all color pigments, depending on the material they are made of and their thickness, appear more or less transparent to different wavelengths of infrared radiation. In many cases, preparatory drawings can be identified beneath the paint layer; it is a whole artistic world that is revealed, a hidden art that becomes available for study and that can tell us how artists worked, how they prepared their compositions, and whether they changed their minds (i.e., had *pentimenti*) during the execution. It is also a good way to reveal copies, which usually do not show *pentimenti*.

Figure 1 and Figure 2 show examples of reflectography enhanced by multispectral colour mapping. In particular, in Figure 1 the false-color image shows more information in the dark areas as well a good differentiation of the pigment under the left hand of the Virgin (compare fig. 1a with fig. 1b). As a second example we consider the masterpiece *Madonna con Bambino* (fig. 2a) of the Santa Verdiana Museum in Castelfiorentino (Florence, Italy). Despite the controversy about its attribution, the most assume it was painted by Cimabue in the second half of 13th century. Furthermore, a very young Giotto could be the author of the Child. Extensive restorations are clearly showed in red and purple, particularly the horizontal imitative reintegration, which filled the gap in correspondence with the junction of the two panels (around the middle of the painting).

HOLOGRAPHY AND BEYOND

Dennis Gabor invented holography, almost by chance, in 1948. For several years it remained little more than a laboratory curiosity until, with the advent of the laser in the 1960s, it exploded, revolutionizing how the images were made, both in science and art.

Unlike photography, holography can also record the phase of the light wave, not just the intensity. This translates, for example, into the possibility of creating three-dimensional images virtually indistinguishable from the original.

The classic holographic technique, the one that was developed in the mid-1960s and would have its golden age in the 1980s-90s, requires a laser source both to record images and to be able to review them. It is a purely analog process in which the image is recorded on a glass plate, covered with photographic emulsion, then developed and observed again.

The process was long, expensive, and technically complex. Dark rooms were required to record and review the image, and stringent stability requirements were achieved through the use of anti-vibration tables, among other measures.

The ultimate prize, for those who overcame all these difficulties, was a three-dimensional image of a quality never before achieved and never again equalled.

Holography aroused the interest of many artists and soon museums entirely dedicated to collecting holograms sprang up.

Fig. 2 - Cimabue, *Madonna con Bambino*, painting on wood, 13th century, Santa Verdiana Museum, Castel-fiorentino (Florence, Italy). a) visible; b) false-color image with IR information mapped as red. (Ambrosini et. al, 2011).



From a scientific point of view, the most significant contribution of holography was the development of a new diagnostic technique, holographic interferometry. By recording two holograms at different times and superimposing them, an image of the object under investigation covered by black and white lines was obtained; these interference fringes provided information on the deformations undergone. Holographic interferometry originated in mechanical engineering but spread rapidly. In the early 1970s, in the newly founded Faculty of Engineering in L'Aquila, the group led by Prof. Franco Gori began to experiment with holographic interferometry for the diagnostics of panel paintings (Amadesi et al., 1974). It was another small revolution in the larger revolution of holography, which initiated the development of many optical methods currently in use for cultural heritage, such as speckle photography, electronic speckle pattern interferometry, shearography, digital holography and correlation methods.

The development of these techniques also coincided with the decline of traditional holographic methods: too slow, expensive and 'difficult' for our contemporary times.

The same decline happened to holography museums, which closed one after the other. Today, the largest collection of holograms open to the public can be found at the MIT museum, where many of the first techniques were developed.

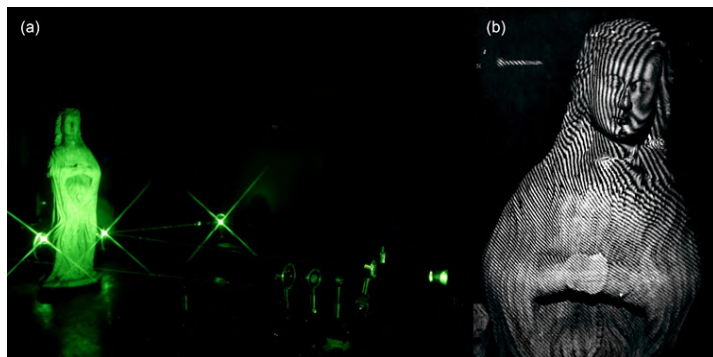
Superimposing two holograms on the same plate will result in two reconstructions of the object, at different times and under different conditions. Visually only one object will appear, covered with black and white lines. Already the availability of a fully three-dimensional copy radically changed the way of looking at objects, even artistic ones, but it was the presence of the fringes the real revolution. From their pattern it was possible to obtain information about the deformations they had undergone and the presence of sub-surface defects not visible.

Photographing an interferogram does not restore the experience of observing it from life, precisely because the three-dimensionality is lost.

A true interferogram, i.e. observed using the laser source, will appear as an exact three-dimensional copy of the object furrowed by a series of black and white lines related to the displacements and deformations undergone, with a sensitivity of the order of fraction of a micron.

From an aesthetic point of view, this is a very beautiful object, in which a technical map is superimposed on the iconographic details.

Fig. 3 - Maddalena, stone statue 13th - 14th century, Santa Maria di Collemaggio Basilica (L'Aquila, Italy). a) Laboratory setup; b) holographic interferogram revealing cracks. (Paoletti et al., 1989).



In the case of artwork diagnostics, the fringes represent isodisplacement lines. Since surface movements are also linked to any non-visible (sub-surface) inhomogeneities, it is as if a topographical map is superimposed on a photograph of a known landscape (the work of art) that is so sensitive as to show the effects of what lies beneath that known surface.

And as we were saying, they can be graphically very beautiful: cracks are highlighted by lines reminiscent of swallows drawn by children, like large Vs; detachments, the great enemy of pictorial surfaces, are vaguely concentric fringes, suggesting a propping bubblelike structure underneath. An example is shown in Figure 3.

IR THERMOGRAPHY

The advent of thermography has added a new dimension to optical methods. With thermography, which thanks to technological developments has become increasingly efficient and now, at least in basic applications, available on smartphones, it is possible to detect a temperature map and translate it into a false color or grayscale image. Once again, a visual image provides information of a different nature: in fact, temperature differences can be used to detect the presence of humidity, appreciate differences in materials, recognize buried structures (such as windows and doors walled up in walls or support frames), and identify defects present beneath the surface (Ibarra-Castanedo et al., 2008; Ambrosini et al., 2010; Paoletti et al., 2013; Gavrilov, Maev & Almond, 2014). In the architectural field, the identification of buried structures (masonry, arches, etc.) can be of considerable help in reconstructing the modifications undergone by the artifact over time.

CONCLUSIONS

Optical methods have revolutionized the way we study, restore, and appreciate artworks. These techniques allow us to gain valuable insights into the physical and chemical properties of artworks, as well as their historical context and artistic techniques. Optical methods have provided new avenues for art conservation, enabling restorers to identify and treat problems that would otherwise have been undetectable. Moreover, these methods have allowed us to appreciate artworks in new ways, revealing hidden details, beyond what is visible to the naked eye, and shedding light on the creative process. With the help of optical methods, we can continue to unlock the secrets of our cultural heritage, ensuring that it is preserved for future generations to enjoy.

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Cover figure - Details from holographic interferograms, realized in Las.E.R. Lab (University of L'Aquila, Italy), on paintings on wood and gold icons of 13th - 15th centuries..