THE EXTRAORDINARY ROLE OF THE IMAGING TECHNIQUES IN THE CONSERVATION AND VALORIZATION OF CULTURAL HERITAGE

Mauro Matteini
ICVBC – C.N.R.
Florence, Italy

Introduction

In recent decades, modern technologies have pervaded every activity of Cultural Heritage with an incredibly growing pace. All the areas have benefited from that, starting with **knowledge** (with the availability of increasingly sophisticated archaeometric analyses), **conservation** (within the activities of diagnostics, restoration, preventive conservation, monitoring), f**ruition** and **valorization** (through the multimedia-ICT and the lighting techniques), **security** and s**afeguard** (thanks to a variety of electronic sensors implemented against theft, vandalism, environmental degradation, catastrophic events, transport damage), to d**ocumentation** (with the precious digital imaging systems) and **archiving** (with the databases and the software to access the archives of documents and images).

A new generation of specialists have emerged that have adapted their specific skills to the needs of CH, professional figures who find employment in museums, in art and restoration exhibitions, in public and private scientific laboratories, in the archives of CH. The Cultural Heritage, traditionally considered a land of humanistic knowledge and competence, has become a context of interaction, integration, meetings, comparisons between art historians, architects, archaeologists, restorers, together with chemists, physicists, biologists, geologists, engineers, technologists, to the full advantage, in the broadest sense, of the CH.

The Imaging techniques

Among a so wide variety of new technologies involved in this new mega-system, here we want to focus to the *imaging* techniques.

The introduction of *Film Photography*, in the early decades of the 19th century, although initially only in black and white, introduced a real revolution. Now works of art could be not only observed, drawn, painted, but recorded in an objective document, stable, ready to be easily examined by several specialists, in the same time as well as in a successive moment.

Documentation, diffusion of images, possibilities of comparison have expanded as never before. With the development of *Color Photography*, towards the end of the same century, the photographic document has grown furthermore in accuracy of reproduction: color is a fundamental parameter for works of art and paintings in particular, although treatises of art history have continued for decades to illustrate figures in black and white, probably for cost reasons.

In the final part of this paper, we will come back to photography with the topic of the *digital images*, to explore the enormous potentiality of this photographic technique developed in later times.

Among the variants of photography, the *Raking Light Technique* is worth of a special attention. Micro and macro deformations of the surface, induced by degradation processes active along centuries, resulting in swelling, flecking, loss of material, formation of lacunas, efflorescence and other similar alterations, inevitably have affected any ancient artifact. With a photograph taken in raking light, any alteration of the object surface is amplified; its location and the extent of the phenomenon are highlighted.

Raking Light Photography is equally useful for studying the techniques of execution, in a painting, for instance, thickness and orientation of the brushstrokes; in a fresco, the so called *'day's works'*.

Under the Optical Microscope, thanks to magnification, imaging offers the expert an extremely powerful tool to enter within the constitutive material of an artifact, revealing a quantity of information on morphology, colors, sequence of layers in the *Cross section* of a sample. Finally, with the advent of the

Scanning Electron Microscopy, *SEM*, (3rd decade of the 20th century), the study of the surface morphology sample has reached the highest levels.

At the end of the 19th century a new extraordinary *imaging* technique is invented: *Radiography*. Not only the external appearance of an object can be documented, as it had always been, but its interior too, revealing material structures inaccessible to the eye. X-rays, a radiation with infinitesimal wavelengths ($\lambda \approx 10 - 10^{-3}$nm), much shorter than the visible light ($\lambda \approx$ 700 nm/red - 400 nm/ violet), competitive with the atoms size (about 0,1nm), allow to cross solid bodies, depending on their thickness and composition.

In the second decade of the 19th century (1916-18) some more advanced museums begin to radiograph art-objects in a systematic way. Discoveries follow each other in an enthusiastic way: unthinkable artist's *pentimenti* are brought to light, multiple paintings overlapped on the same panel or canvas are revealed, internal pivots are identified inside wooden statues.

Radiography is the first major ascending step in the world of *diagnostic imaging*. Once undertaken, this new road will be expanded with the use of even more penetrating radiations, *gamma rays* with wavelengths in the range $<10^{-3}$nm, but above all with greater energy.

They are capable of crossing much larger thicknesses than those of panel paintings, and materials much more compact than wood: i.e. metals, stones. This opens the way to identify and locate elements inside bronze, marble, stone sculptures, to measure thicknesses, identify joints, welds, diagnose the presence of internal cracks and other discontinuities; practically, the possibility of acquiring a wide range of information both on the structure of artefacts and their state of conservation.

Going even further in the ability to penetrate very thick structures, in very recent years a decidedly futuristic application has appeared: the use of ultra-high energy radiation, made of *Muons*, subatomic particles with a charge similar to that of electron and mass about 200 times higher. Muons are highly unstable particles with a very short life time, that, however, can reach the earth's surface coming from the atmosphere boundaries, originated from cosmic rays. Recently they have been successfully employed looking for new internal chambers in the Pyramid of Cheops. They are going to be applied to the Dome of the Florence Cathedral in search of possible internal metal chains.

Going back to more accessible technologies, other radiations close to the visible range, overlook the art world: the *Ultraviolet* ($\lambda \approx$ 400nm - up to the XR), in use since the 2nd decade of the 20th century, and the *Infrared* ($\lambda \approx 0.7\mu$m - 0.4mm), from the 3rd decade of the same century.

Also these radiations are recorded on photographic film. They subdivide in a number of specific techniques according to the *taking* conditions (source of the radiation, filters to select the source, types of film to record the images, etc.).

The *Ultraviolet* is distinguished in *Reflected UV* and *UV Fluorescence*. A reflected UV image is directly recorded on the film while in the second case the fluorescent visible image excited by UV is recorded. *Reflected IR* is quite similar to *Reflected UV*: the reflected IR image is recorded on a special film. Initially, various types of black and white films were used, the only available at the beginning of these experiences. For decades the availability of only black and white films has been a limiting factor that penalized the above techniques, especially *UV Fluorescence* which manifests as a color image. As soon as *Color Photography* became available it was possible to record in their fullness the specific fluorescence-colors depending on the nature and the age of the materials of the object.

Later on (over the 70s of the 20*th* century) *false colors infrared films* were introduced, capable of mutating an Infrared-Red-Green image (Blue is excluded by a filter) in a 'false' Red-Green-Blue image. Thus, a new technique was born, the *Infrared False Colours*.

The use of these 4 techniques is based on the specific way UV and IR radiation interact with the constituent materials of the objects, which is different from that of light. By comparing the UV or IR images with those obtained with common light, very important information, although not foreseeable a priori, can be

acquired on the nature of materials and figures not visible or not differentiable by eye.
But there is a further possibility. Depending on wavelength, the infrared radiation can penetrate more or less into matter. This makes it possible to differentiate in a painting, also materials (or figures) located below the paint layer, such as preparatory drawings, *pentimenti*, etc..
Starting from the '80s, with the development of opto-electronic technologies, photographic films were replaced by cameras, powerful instruments, able to go beyond the visible, in the infrared region. In this range some of the surface paint layers become more transparent. This is how *Infrared Reflectography* was born, initially realized with cameras and later, with more sophisticated Laser-Scanners in the Visible-Infrared region. *IR Reflectography* and *IR-VIS Laser Scanners* are today the techniques of excellence to explore the hidden layers of a painting, especially the preparatory drawings, with striking results that have unveiled the evolution of an artist in his creative activity.
With the VIS/IR Laser Scanner it was possible to reproduce the *IR-False Color-Photography* with a precision that amazes. But today, IR-False-Color can also be realized with some *special digital photo-cameras*. In an analogue way also a *Digital False-color-Ultraviolet* technique has been implemented.
We started this extraordinary path of technological innovations applied to Cultural Heritage with *Film Photography*. This technique, this period, are now almost extinct. Digital Photography has penetrated in any context. Phones, tablets, digital cameras of recent generation are available to all, at affordable prices. Taking digital photographs is nowadays a diffuse practice. The advantages are too many and too suggestive. You can take photos at will, evaluate, discard the badly-done, save the good, perfect your takes with software that allows you any processing, finally archive on digital supports without space problem; if you want, you can print your photos with excellent colour renditions.
To complete this overview we want now to come back to the normal digital photografy but that at an excellence level, the so called High Definition Digital Photography (HDDPh), which can only be realized with professional equipment by specialized operators. The role of this special digital Photography has been remarkable, not only for storing the reproductions of the art-objects in Museums archives (which other document, if not a HDDPh, could be more accurate and reliable?) but also as a powerful tool for studying artworks at disposition of art-historians, archaeologists, architects. Sitting comfortably in their office, they can examine their images on a monitor, enlarge them at will, highlight any figurative or material detail undetectable by other means: in practice, a boundless possibility of study.
In the field of conservation, not to mention the ease of documenting a restoration in progress in all of its steps, or monitoring the evolution of the state of an artefact post restoration, we want to focus here on a powerful application, rich in promising developments: the *Virtual Digital Restoration*. I am well aware, from personal experience as well, how this approach is still considered with prudence by experts (art-historians, etc.). The hesitation, which I consider unfounded, comes from idea that it could become competitive with the 'real' restoration. On the contrary, let's think about the advantages that this availability could offer a public or private restoration organism. For instance, once the canonical operations (cleaning, consolidation, filling) were finished, it would be possible to simulate in advance a series of possible solutions for the final step of restoration, the so-called aesthetic restitution, without intervening on the object with choices that, in retrospect, might be not the most appropriate. This not only valid in the restoration area but for example for deciding the way to expose an artwork in a Museum, or for setting an exhibition, and so on. A variegate opportunity, about which it is convenient that the stakeholders reflect seriously, to evaluate, without prejudices, the undoubted advantages.
To illustrate adequately each of the numerous *imaging technologies for C.H.* developed in the last few decades, a treatise would be needed. With the present contribution we tried to give, at least, an overview about the crucial role they are playing today in favour of conservation, knowledge and valorization of Cultural Heritage