Integrating Optical Imaging and Digital Processing for Nondestructive Diagnosis of Artifacts

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Summary

As opposed to single-point analytical techniques, nondestructive diagnosis of cultural heritage objects by specialized imaging does not require microsampling to provide information about the chemical composition and the status of conservation of the materials, but has often a poor accuracy as a tool for restoration.

Nevertheless, optical imaging with different modalities, when associated to suitable processing, is able to distinguish between different materials and patterns, to reveal hidden features of the objects under study, and to produce panoramic maps useful to guide more powerful analytic tools towards the most interesting target areas.

Our approach to specialized imaging for nondestructive diagnosis integrates multispectral and 3D capture, from which material and structural information can be gathered, and various processing techniques from which all this information can be extracted and provided with its true meaning.

Detection of Hidden Details

- A linear data model

The appearance of the object under test is assumed as resulting from a linear superimposition of source images, each composed of a channel-independent spatial pattern multiplied by a specific, possibly unknown, emission spectrum. The data cube of the appearance image can thus be expressed as

$$x_k(i,j) = \sum_{m=1}^{N_{patt}} a_{km} s_m(i,j); \quad k = 1, \cdots N_{chann}$$

where $x_k(i,j)$ is the *k*-th component of the data cube at pixel (i,j), $s_m(i,j)$ is the spatial pattern of the m-th source image at (i, j), and a_{km} is its *k*-th spectral component.

- Linear processing of the data cube

With no hypothesis on a_{km} we can apply a number of linear operators on our data cube to reveal the presence of some $^s m$ that is not detectable in any of the available channels x_k. Ideally, we would like to obtain

$$y_l(i,j) = \sum_{k=1}^{N_{chann}} w_{lk} x_k(i,j); \quad l = 1, \cdots N_{patt}$$

such that $y_l(i,j)$ coincides with some $^s m\ (i,j)$ for all pixels (i, j). Different criteria to choose the *separating* coefficients W_{lk} emerge from different statistical properties assumed for the source patterns, such as mutual independence and uncorrelation. Further processing can then be applied to make the patterns more visible/legible.

- An example from document analysis: reading a palimpsest

Figure x.1 RGB image of a bifolio (17r-16v) from the Archimedes Palimpsest (http://archimedespalimpsest.net). Faint traces of an ancient writing are barely visible under a more recent text. Copyright: The Owner of the Archimedes Palimpsest. Image capture: University of Rochester.

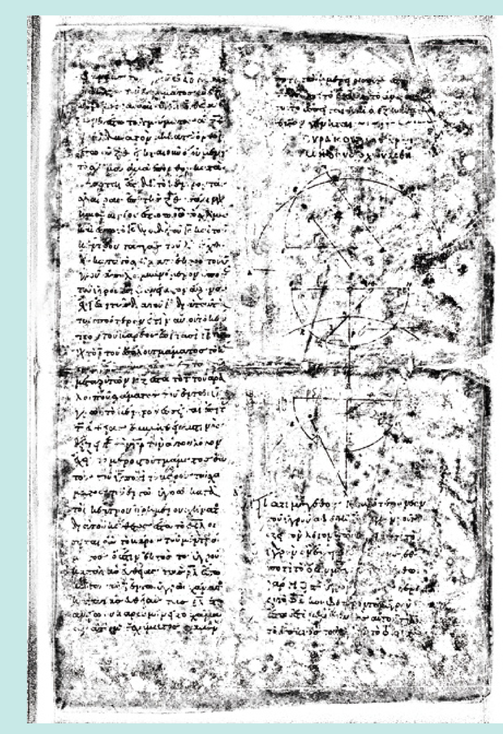


Figure x.2 An output image obtained by decorrelating the RGB channels in Fig. x.1. The underlying text and drawings are now visible. Copyright: The Owner of the Archimedes Palimpsest. Digital processing: Signal & Image Lab, ISTI-CNR

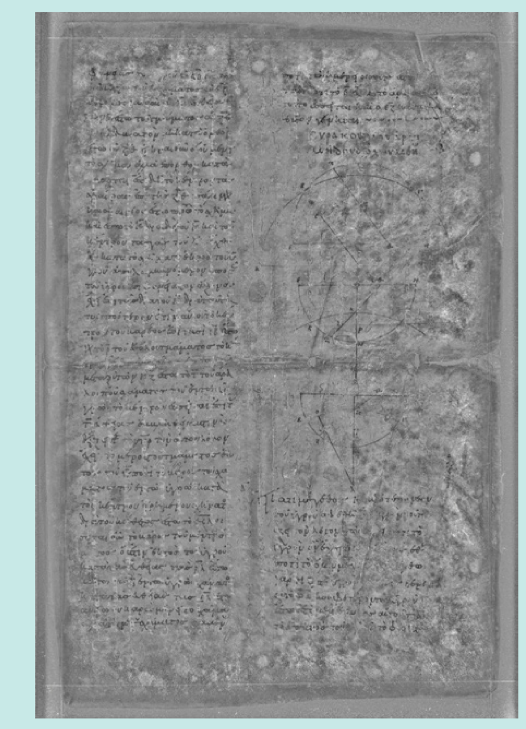
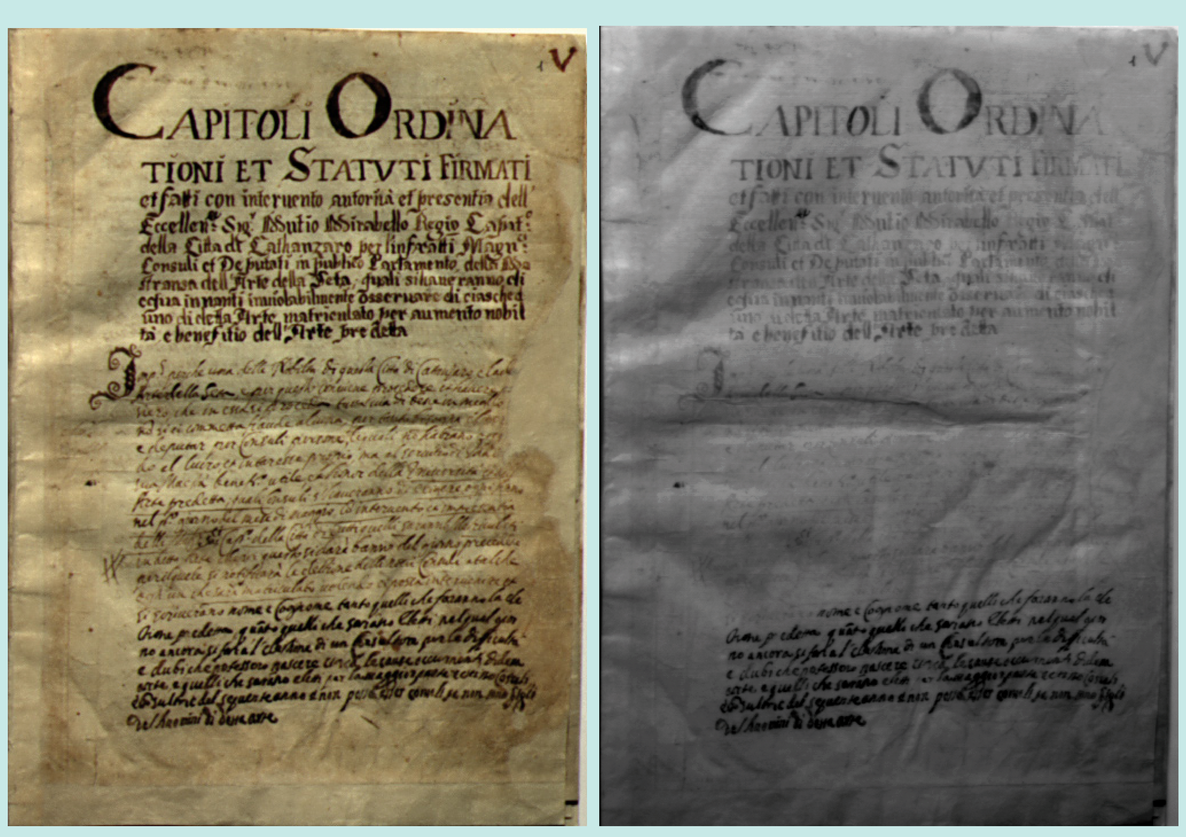
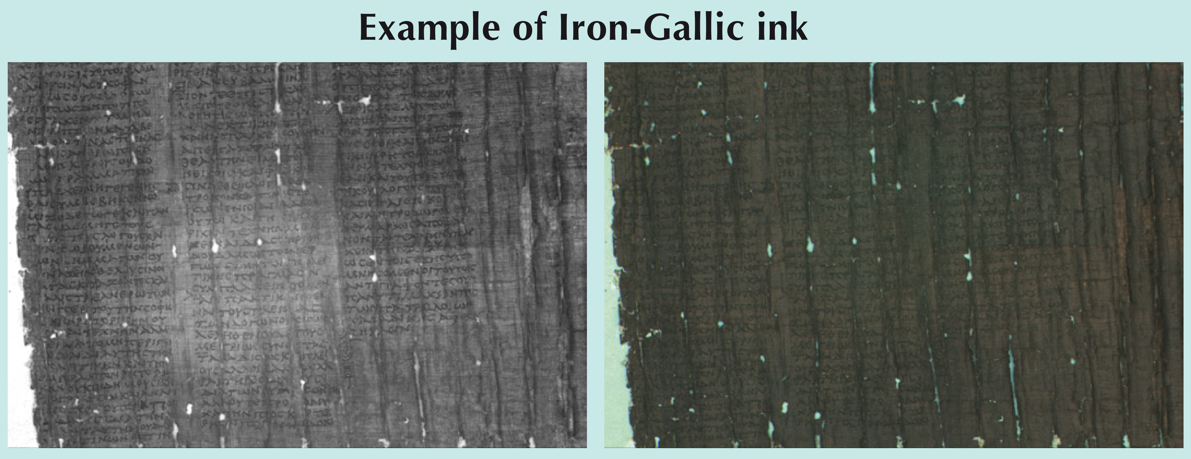


Figure x.3 Visibility enhancement from the result in Fig. x.2. The ancient text pattern is now more clearly readable. Copyright: The Owner of the Archimedes Palimpsest. Digital processing: Signal & Image Lab, ISTI-CNR.

The multispectral techniques allow to identify the type of ink used. For example iron gallic inks absorb energy in the infrared band, so they fade or disappear, unlike carbon inks which may stand out



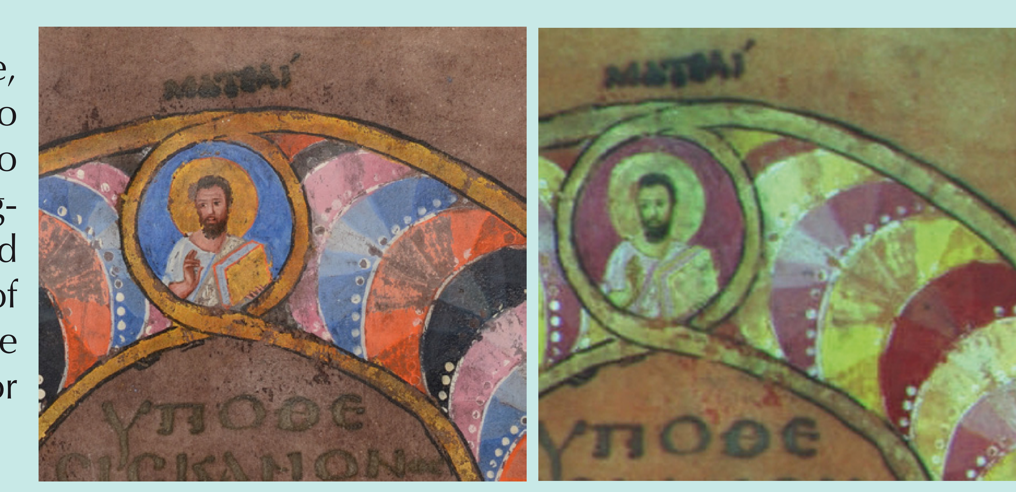
Example of Iron-Gallic ink



Example of Carbon Ink

False colour images are useful for the discrimination of different materials.

In the case of miniatures of a manuscript, for example, the technique delivers a trichromatic image using two components of the visible and the near infrared able to understand the chemical and physical nature of the pigments. Technically, once aligned the images, the band of red is replaced with the near infrared one, the band of green with the red one, and the band of blue with the green one; this operation allows to analyze the behavior of the different pigments in the IR band.



On the figure you can see the behavior of the azurite and lapis lazuli: in the visible range both pigments return a blue color, almost identical; the image obtained by processing the false colors shows that their behavior differs considerably, as the lapis lazuli does not absorb infrared becoming, therefore, magenta, while azurite, absorbing it completely, would have ben dark. The red part of the visible turns into a deep yellow in false color, for which reason, presumably, it is red lacquer instead of cinnabar, which would also become yellow, but much more tenuous and was generally used for coloring of a subject of great importance.

Hardware

At present the tools for the acquisition of works of art are poorly flexible, difficult to transport and quite invasive; moreover there are not software tools specifically dedicated to virtual restoration, and the insiders, often, have to work on common computer graphics software that are not always suitable to their needs.

TEA, CNR-ISTI and UNICAL-DIMEG offer an innovative solution: an integrated tool for the multispectral 3D imaging of cultural heritage, combined with an user-friendly software built on the requirements of the potential users and able to process multiple bands simultaneously.

The imaging device is composed by a multispectral camera and two high resolution cameras. This set-up allows users to simultaneously obtain high resolution photo, multispectral images and 3D data. The system can be configured depending on the object that has to be acquired ranging from miniatures of ancient documents and paintings to large wall paintings. Due to the different scale of the objects to be acquired the acquisition system has been equipped with different optics, and the lighting system has been designed taking into account the various techniques to be used. The 3D system has been appropriately calibrated with the multispectral system for the registration of the two types of data and for the texture mapping of the 3D models. The 3D acquisition technique is based on the projection of structured light patterns. A control unit runs the entire phase of acquisition, data storage and processing. The software is unprecedented, since it allows users to analyze, categorize and store a huge amount of documents, with consequent advantages in terms of time savings and automation.

A special support has been designed and built in order to simultaneously mount the imaging devices (multispectral camera, projector, two high resolution cameras) and to allow an easy handling of the system also for reaching the parts of the artefacts that are difficult to be acquired.

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ITACA

"Everything that is not seen exists"

Innovative Tools for cultural heritage ArChiving and restorAtion

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