MULTISPECTRAL ANALYSIS OF CULTURAL HERITAGE ARTEFACTS

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Abstract. *Several methods of nondestructive optical testing of works of art are described and analysed in the contribution. Main attention is paid to analysis of near infrared reflectography, ultraviolet fluorescence method and X-ray radiography. These methods give us possibility to reveal underdrawings in paintings, older compositions of picture, hidden signatures and retouched areas of works of art without any damage of them.*

Keywords: CCD camera, near infrared reflectography, underdrawing, fluorescence, radiography

1. Introduction

Nondestructive testing methods of cultural artefacts are very important tools for restorers and art-historians to get valuable information about works of art without causing any, even local, damage of them. Known and also widely used are nondestructive methods connected with use of X-ray radiation – radiography, ultraviolet radiation – UV fluorescence and near infrared radiation – IR reflectography. These methods give possibility to reveal overpainted pictures, underdrawings, hidden signatures and therefore provide information about early composition, development and present state of an artefact under test. Results of nondestructive testing methods play often crucial role also in the process of determination of genuineness of a work of art.

2. Near infrared reflectography

Some artist used underdrawings to sketch composition of a picture on its ground layer. For some of them was underdrawing rigid guide for painting the picture by brush, others sketched more freely and in final painting did not follow the underdrawing precisely. It is quite clear that presence of an underdrawing and its relation to the final painting is very important characteristics of artist’s technique and can help art-historians to distinguish for example an original picture from a copy. As underdrawing is covered by other layers (pigments, varnish), it is obvious, that a nondestructive method must be used to reveal an underdrawing without destroying the painting. This method is called infrared reflectography and use near infrared light in the band (0.8 – 2) μm. Method is based on the fact, that pigment’s layer of painting absorb much less infrared radiation in this band comparing to visible radiation. Radiation incident on carbon-based underdrawing is strongly absorbed and therefore infrared light reflected from picture takes information about presence of an underdrawing. For the reflectance R of a uniform layer of pigment with certain thickness x can be derived [1] formula:

$$R = \frac{1 - R_s\left(a - b \cdot \coth(bSx)\right)}{a - R_s + b \cdot \coth(bSx)} \qquad (1)$$

where $a = \dfrac{S+K}{S}$, $b = \sqrt{a^2 - 1}$

and S is scattering coefficient of the pigment layer
K is absorption coefficient of the pigment layer
R_s is reflectance of the support layer

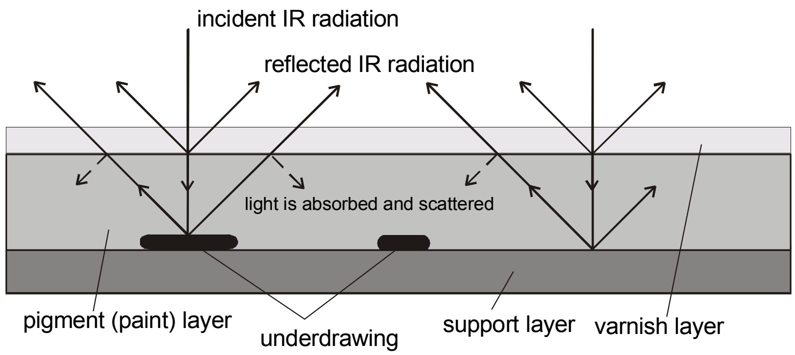

Fig. 1
Penetration of IR radiation in layers of picture

In the case, if on opposite side of pigment layer is a layer of underdrawing, similar equation can be derived:

$$R = \frac{1 - R_U\left(a - b\cdot\coth(bSx)\right)}{a - R_U + b\cdot\coth(bSx)} \tag{2}$$

where R_U is reflectance of underdrawing.

From equations (1), (2) follows that light reflected from painting carries information about underdrawing. Optical contrast of underdrawing image will increase if

- thickness x of pigment layer decreases
- scattering and absorption coefficients S and K of pigment layer decreases
- difference between reflectance of support layer R_s and underdrawing R_u increases.

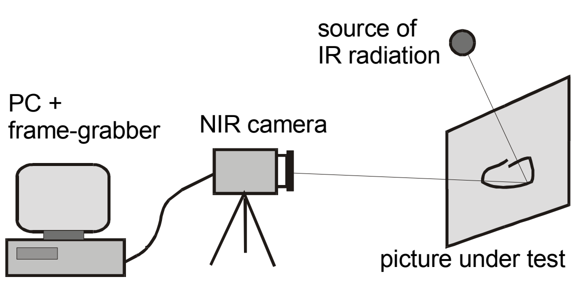

Fig. 2 Basic configuration of an IR reflectographic system.

Basic configuration of an IR reflectographic system is on Fig. 2. Picture or other work of art under test is uniformly irradiated by source of IR radiation (tungsten lamp) and radiation reflected from picture is detected by near infrared camera coupled with frame-grabber and personal computer. Concerning the selection of the band of the spectral sensitivity of camera, optimal is band up to 2 µm (e.g. camera INDIGO ALPHA NIR with spectral response from 0.9 to 1.7 µm, detector array InGaAs 320x256 pixel). These cameras are expensive and have small spatial resolution yet. Many pigments have their absorption coefficient small enough also in the band (0.8-1.1) µm and therefore silicon CCD camera with 0.8 µm short-wavelength cut filter (Schott UG8) can be used. Filter suppresses sensitivity of detector in visible band and advantage of such solution is besides the lower price also great spatial resolution of contemporary silicon CCD arrays (more than 7 millions of pixels). Signal from camera is digitised by frame-grabber and image is than digitally processed in personal computer and after that can be printed or presented on computer screen. Comparing to classical IR photography has digital IR system several advantages:

- real-time information about presence of underdrawing
- better quality of IR images due to digital image processing
- possibility to digitally compare infrared and visible images.

Example of results of infrared reflectography system application is on Fig. 3. System developed in our department was used to investigate a gothic oil painting on wood (dated to the year 1570) from the church in Stará Lesná, Slovakia. The picture was restored by the Department of Restoration, Academy of Fine Arts in Bratislava.

Fig. 3a Gothic painting on wood (dated to the year 1570) from the church in Stará Lesná, image in visible band

Fig. 3b The same painting, image in near infrared band with clear visible underdrawing sketched by charcoal

3. Ultraviolet fluorescence.

Fluorescence is kind of luminescence (emission of light exclusive of thermal sources) by which some substance (e.g. pigment) irradiated by electromagnetic radiation – ultraviolet light is emitting light of visible color. Unlike phosphorescence light is emitted only while the UV stimulation continues. UV fluorescence facility consists (see Fig. 4) from a source of UV radiation (e.g. lamp HQV 125, λ=375 nm), excitation filter (short-wavelength-pass) which cuts off wavelengths overlapping fluorescence, barrier emission filter (short-wavelength-cut) which cuts off reflected UV radiation (undesired fluorescence background, possible injury to eye or sensor) and image sensor (e.g. CCD camera). Old paint or varnish layers under UV emits more fluorescence light comparing to newly applied materials (repainting or retouching area) and therefore retouched areas of the picture appear in fluorescence image darker. UV fluorescence can be also used to visualise

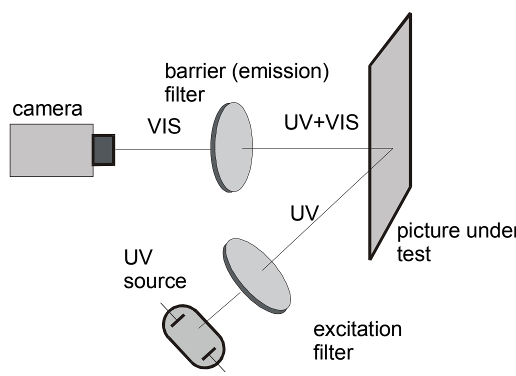

Fig. 4 UV fluorescence scheme

old documents that became during the time invisible. An example of small fragment of visualised mediaeval document (cooperation with Slovak National Archive) is on Fig. 5.

Fig. 5a Fragment of mediaeval document in visible light, text is invisible to a human eye

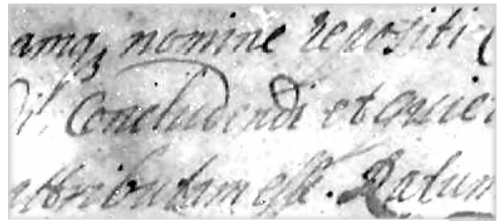

Fig. 5b Fragment of mediaeval document visualised by UV fluorescence method

4. X-ray radiography.

Radiography is nondestructive testing method, by which an object is irradiated by X-rays with wavelength in the band 10^{-7} to 10^{-11} m. When crossed the object partially absorbed rays are registered on photographic film, luminescence screen or matrix semiconductor detector. Absorption of X-rays depends on object's thickness and on a power of atomic number of crossed material. Radiograms can therefore be used to identify pigments (pigments containing heavy metals e.g. lead absorb X-rays more than other pigments) and to reveal changes in composition of a picture.

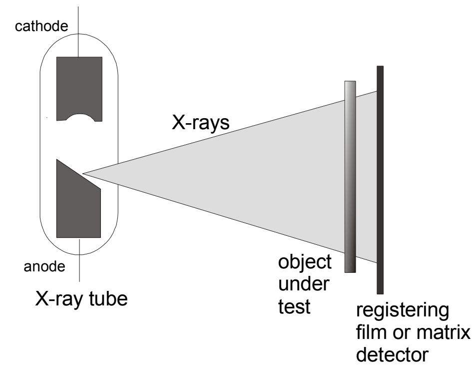

Fig. 6 Basic configuration of X-ray radiographic system

5. Discussion.

Preserving of cultural heritage is very important and at the same time very complex problem. Described nondestructive testing methods of works of art are useful tools for art-historians and restorers and help them to do these tasks. Infrared reflectography is appropriate method to reveal underdrawings containing carbon, ultraviolet fluorescence method helps reveal retouched or newly repainted areas of a picture and X-ray radiography gives information about older compositions of a picture under test. Although described methods are known for many years, contemporary a new quality of results can be reached by use of state of art sensors and applying of digital image processing, dramatically improving results of all these methods.

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