3D spectroscopic mapping tomography applied to art objects diagnosis

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Abstract

In this work, acoustic microscopy, infrared reflectance spectroscopy and imaging, Raman and microRaman spectroscopy is used in order to study the stratigraphic structure of a painted art object. The tomographic images in a region of interest (ROI) of the art object is acquired using acoustic microscopy and the distribution of the materials in the ROI is acquired using infrared reflectance and raman spectroscopy. Using the acquired spectra from both the spectroscopies (Infrared and Raman) the 3D segmentation – clustering of the spectra dataset acquired from the ROI of the painted art object in order to display in high resolution the distribution of the materials in the stratigraphy. The clusters are consisted of spectra that have similar characteristics (for both the modalities Infrared and Raman) and thus are indicating the existence of similar materials; hence, similar chemical composition. The spatial distribution of such clusters can be illustrated in pseudocolor images, in which each pixel of image is colored according to its cluster membership. Such mapping images convey information about the spatial distribution of the chemical substances in an object.

An ALPHA (Bruker) infrared spectroscope with special adapted reflectance illumination area and a micro exRaman (BWTEK) where used in order to acquire the array of spectra and a custom acoustic microscope for the acquisition of the tomographic data (Figure 1). The spectral area in the infrared area of the spectrum covered by ALPHA is from 7500-375cm^{-1}. The Raman laser source that is used has excitation in 1064, i.e., near infrared (NIR). Both the wavelengths that are used form both the spectroscopic modalities ensure the penetration of the radiation in deeper layers. Furthermore, the optical microscopy camera, where the Raman probe is plugged in, is attached to a computerized numerical control (CNC) system which is driven by a software that is specially developed for the scanning of the object with the probes of all the modalities (Acoustic Microscopy, Infrared reflectance spectroscopy and Raman spectroscopy) (Figure 1 and Figure 2). Thus, the mapping images that are produced by clustering the acquired spectra (specifying specific bands of Raman shifts and wavelength bands of infrared spectra) can provide stratigraphic information in the mapping images, i.e., images that convey information of the distribution of substances from deeper, as well. To cluster the spectra, unsupervised machine learning algorithms are applied, e.g., hierarchical clustering. The clustering images derived by the Raman and infrared modalities are registered on the tomographic images providing to the user a high fidelity information of the distribution of the materials in the 3D structure. The whole dataset is supported by the infrared reflectoscopy images acquired from the icon using the well-known infrared reflectoscopy imaging technique providing the user pictorial information on the existing beneath icon. This software except for the conventional CNC operation allows the user to parametrize the spectrometer and check each and every measurement to ensure proper acquisition. This facility is important in painting investigation because some materials are vulnerable to such specific parametrization that other materials demand.

The technique is tested on a portable experimental overpainted icon of a known stratigraphy. It could be referred also as a phantom painting (Figure *3*). The two byzantine paintings that consist of the experimental icon, the one of the top of the other, and the region of interest (ROI) where the spectra acquired are illustrated in Figure 2. Finally, the results of the investigation, i.e., the stratigraphic mapping imaging of the ROI, are illustrated in revealing features from the under icon. Specifically, the under icon, i.e., the wavy hair of ``Saint James", can be separated from upper icon, i.e., the halo of Mother of God in the ``Descent of the Cross" (Figure *4*). The clustering images derived by the Raman and infrared modalities registered on the tomographic images and the infrared reflectoscopy images are provided in Figure 5 and Figure 6.

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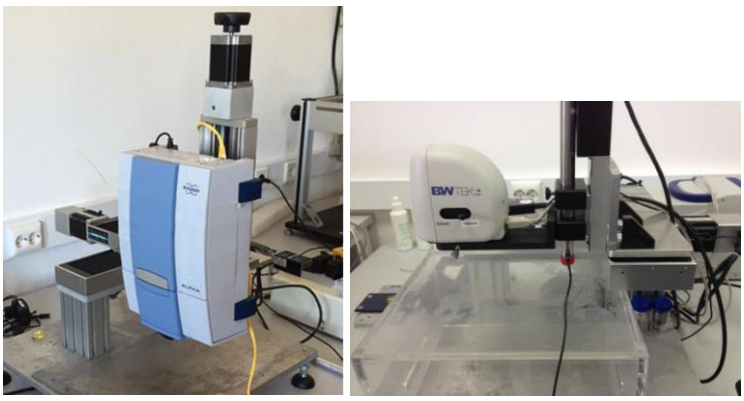
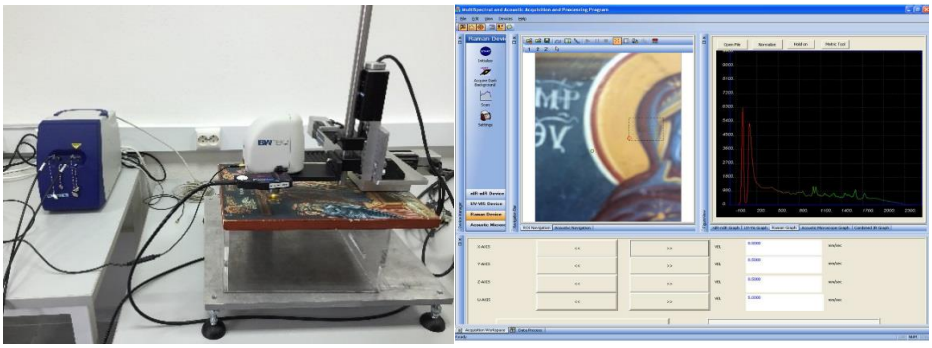


(a) (b)

Figure 1: Infrared ALPHA (a), Raman (b) System and the acoustic microscopy transducer(b) mounted on the XYZ moving stages (CNC) system.



(a) (b)

Figure 2: Acquisition using the Raman System: (a) Hardware part, Raman spectrometer, probe and the micro–camera mounted on the XYZ moving stages (CNC) system. (b) Software part, the control of the CNC and the Raman device for the acquisition of spectra in the specified ROI.

(a) (b) (c)

Figure 3: The experimental icon ``Descent from the Cross". The icon contains two pictures, one of top of the other. The scene of the ``Descent from the Cross" was painted over the icon of (c) ``Saint James", which was vertically half covered with an intermediate preparation layer and (b) is the superposition of the picture in (a) and the picture in (c).

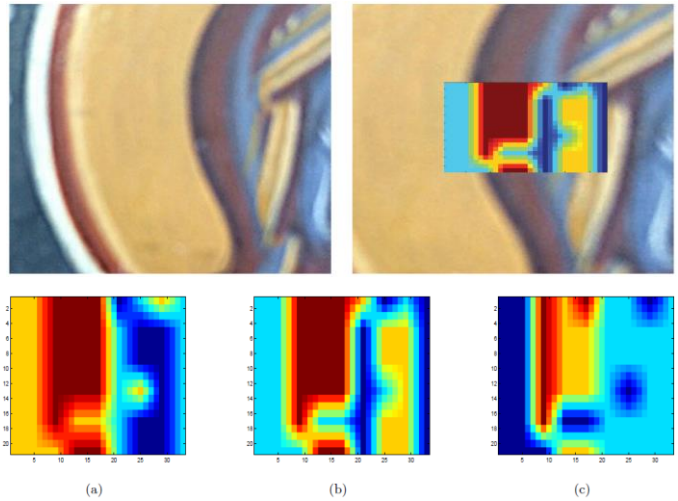


Figure 4: Clusters of the spectra in the ROI for three Raman shift bands. These bands in wavenumbers are (a) 0 – 2500 cm^{-1}, (b) 600 – 1000 cm^{-1} and (c) 1400 – 1800 cm^{-1}.

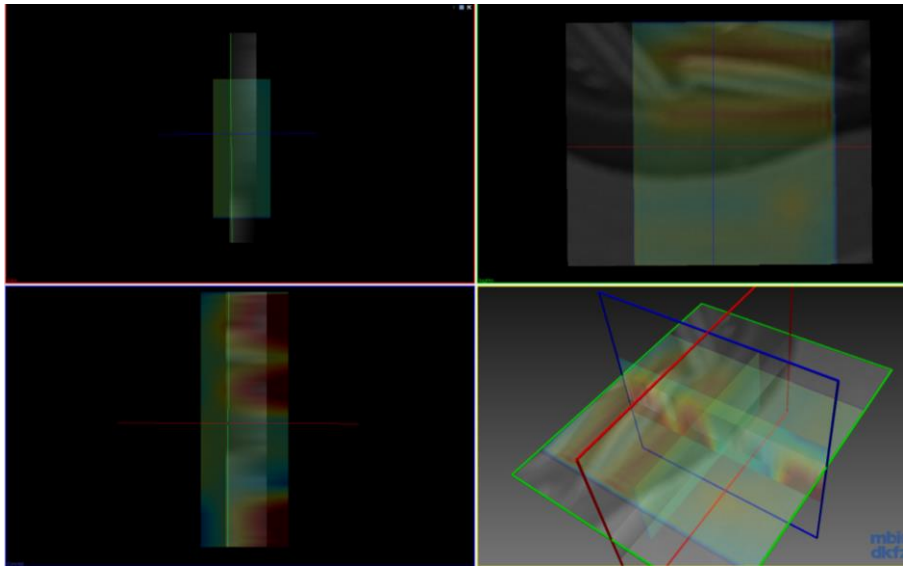


Figure 5: The raman and inafrerd clustering images registered on the infrared reflectoscopy images.

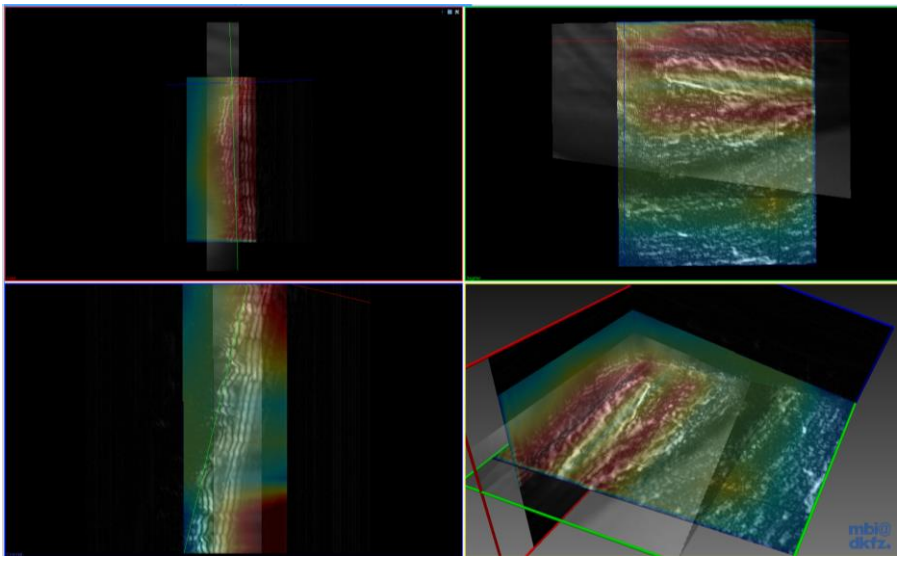


Figure 6: The raman and infrared clustering images registered on the tomographic images and the infrared reflectoscopy images.

References

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