Sparse Macro-XRF Imaging of Large Works of Art

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In the last decade, macro-X-ray fluorescence (MA-XRF) imaging has become an established non-destructive analytical technique for the investigation of distribution of elements across wide fields of view on works of art, mainly paintings. The particular advantage of MA-XRF in comparison to other spectral imaging techniques is that it reveals the elements composition present at the surface and sub-surface of the paint layer, thus rendering itself particularly suitable for the characterization of the artist's creative process, as well as of the artwork's conservation history. However, the larger the area covered during an MA-XRF scan, the longer the time necessary to complete the scan.

In this work, we present a novel MA-XRF imaging system developed specifically to decrease the scanning time of large areas significantly through an adaptive sampling scheme coupled to machine learning. The system is composed of an XRF spectrometer mounted to a motorized gantry designed to collect only a sparse sampling of pixels that represents total variation of the scene. The pixel selection is based on the generation of a binary mask, calculated either randomly from a statistical distribution or from a convolutional neural network trained on a series of natural images. Reconstruction of the complete scene is undertaken by fusing the sparsely collected XRF signal to a conventional high-resolution RGB image, thus producing a datacube with both high spatial and high spectral resolution.

Case studies that explore the potential of sparse MA-XRF imaging, in which it was possible to image the distribution of the main constituents of the paint layer very effectively, will be presented. Due to its capability of combining a short acquisition time with an accurate reconstruction of the elemental distribution, sparse MA-XRF imaging could significantly improve the present practice of chemical imaging of large works of art.