Travelling through Space and Time: A Novel MA-XRF Imaging Method for Separating Sources of Chemical Information in Large Works of Art

Gianluca Pastorelli[a], Emeline Pouyet[a], Neda Rohani[b], Kate Smith[c], Katherine Eremin[c], Oliver Cossairt[b], Aggelos Katsaggelos[b], Marc Walton[a]

[a]Northwestern University / Art Institute of Chicago Center for Scientific Studies in the Arts (NU-ACCESS), Evanston, IL

[b]Department of Electrical Engineering and Computer Science, Northwestern University, Evanston, IL

[c]Harvard Art Museums, Straus Center for Conservation, Cambridge, MA

Contact Author's E-mail Address: gianluca.pastorelli@northwestern.edu

Macro-X-ray fluorescence (MA-XRF) imaging has become an established non-destructive analytical technique for the investigation of distributions of elements across wide fields of view on works of art, mainly paintings. The advantage of MA-XRF in comparison to other spectral imaging techniques is that it reveals the elemental composition not only at the surface, but also at the sub-surface of the paint layer, rendering the technique particularly suitable for the characterization of the artist's creative process, as well as the artwork's conservation history.

A method based on fusing a low-resolution XRF signal to a conventional high-resolution RGB image, thus producing a datacube with both high spatial and high spectral resolution, was previously proposed to address the often prohibitive acquisition times necessary to perform MA-XRF scans of large surface areas [1]. However, in paintings with hidden layers there is no perfect correspondence between the XRF data and the RGB color information, since underlying paintings cannot be detected with visible light but can be using X-ray wavelengths. This work presents a case study that explores the possibility of effectively separating the surface and hidden distributions of elemental constituents from a set of mixed XRF signals, while keeping the scanning time of large areas significantly low.

Paul Gauguin's *Poèmes Barbares*, which displays a Tahitian animal-god accompanied by a winged female figure, was subjected to X-ray radiography, revealing an entirely different composition below the surface. A clearer understanding of this hidden image, depicting a small Tahitian landscape with two horses and riders, required a determination of the pigments comprising the palettes of the surface versus the invisible painting. An MA-XRF analysis was undertaken using an XRF spectrometer mounted to a homebuilt motorized two-dimensional scanner designed to collect chemical distributions across large painted surfaces *in situ*. The XRF maps were overlaid onto the RGB and the X-radiograph images, to separate and visualize the elemental distributions associated with the surface picture and the hidden landscape respectively. The reconstruction of the underlying chemical information made it possible to compare the palette of the landscape to other similar paintings made by Gauguin and determine what role this small painting may have played in the artist's oeuvre.

Due to the capability of combining a short acquisition time with an accurate representation of individual chemical signals from the visible surface and the hidden layers of a painting, MA-XRF source separation imaging could significantly improve the present practice of chemical imaging of large works of art.

1. Dai, Q., Pouyet, E., Cossairt, O., Walton, M. and Katsaggelos, A.K., 2017. Spatial-Spectral Representation for X-Ray Fluorescence Image Super-Resolution. *IEEE Transactions on Computational Imaging*, *3*(3), pp.432-444.