Intelligent Analysis of Element Distribution Maps Acquired with a Full-Field XRF Imaging Spectrometer

T. Fiutowski†, W. Dąbrowski, S. Koperny, B. Łach, B. Mindur, T. Szumlak, P. Wiącek

AGH University of Science and Technology, Kraków, Poland

Faculty of Physics and Applied Computer Science

Abstract

X-ray fluorescence (XRF) imaging technique has been proved to be exceedingly useful for the non-invasive investigation of cultural heritage objects in recent years. It offers the possibility to study spatial distributions of inorganic pigments on the surface of artworks and in the hidden painting layers, making it a widely used tool for investigation of the provenance and authenticity of the objects as well as to study the artist's technique and its workshop. The goal of this work is to investigate the possible application of intelligent analysis for processing XRF data acquired with a full-field XRF spectrometer employing a position-sensitive and energy-dispersive Gas Electron Multiplier (GEM) detector. Our system is equipped with two molybdenum air-cooled X-ray tubes to ensure homogeneous illumination of an investigated area, pinhole optics for image projection, a copper-less GEM detector [1, 2], and custom-designed readout electronics with a dedicated data acquisition system. The system achieves a spatial resolution of about 1 mm and energy resolution at the level of 17% FWHM (for 5.9 keV). In the paper, the design and performance of the full-field imaging spectrometer and the results of case studies performed using the developed instrument are presented. Special emphasis is placed on the factor analysis methods like Non-Negative Matrix Factorisation (NMF) and Principal Component Analysis (PCA) which can provide significant enhancement of selectivity of the elemental analysis in case of the limited energy resolution of the spectrometer [3].

Measurement system

- Measurment head mounted on the industrial robot arm.
- Two molybdenum air-cooled X-ray tubes.
- Pinhole optics for image projection.
- 10×10 cm^2 copper-less GEM detector with 2-D cartesian readout [1, 2].
- Ar/CO_2 (70/30) gas mixture.
- Custom designed front-end electronics (ARTROC ASICs [4]).
- Custom designed ADC/FPGA readout boards with Gigabit Ethernet interface.
- Workstation PC with Linux based operation system.

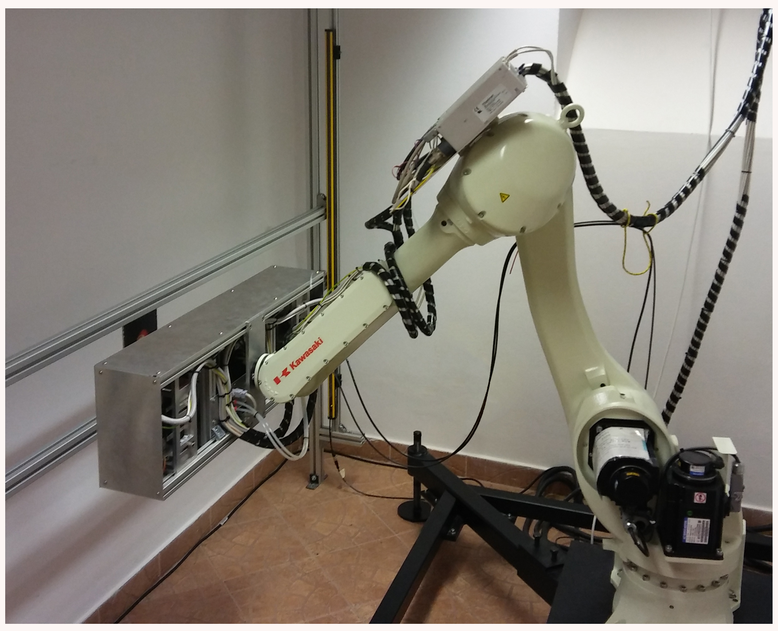

Figure 1. **Photo of the full-fied XRF spectrometer installed at the National Museum in Krakow [3].**

Comparison of results for three different analysis methods

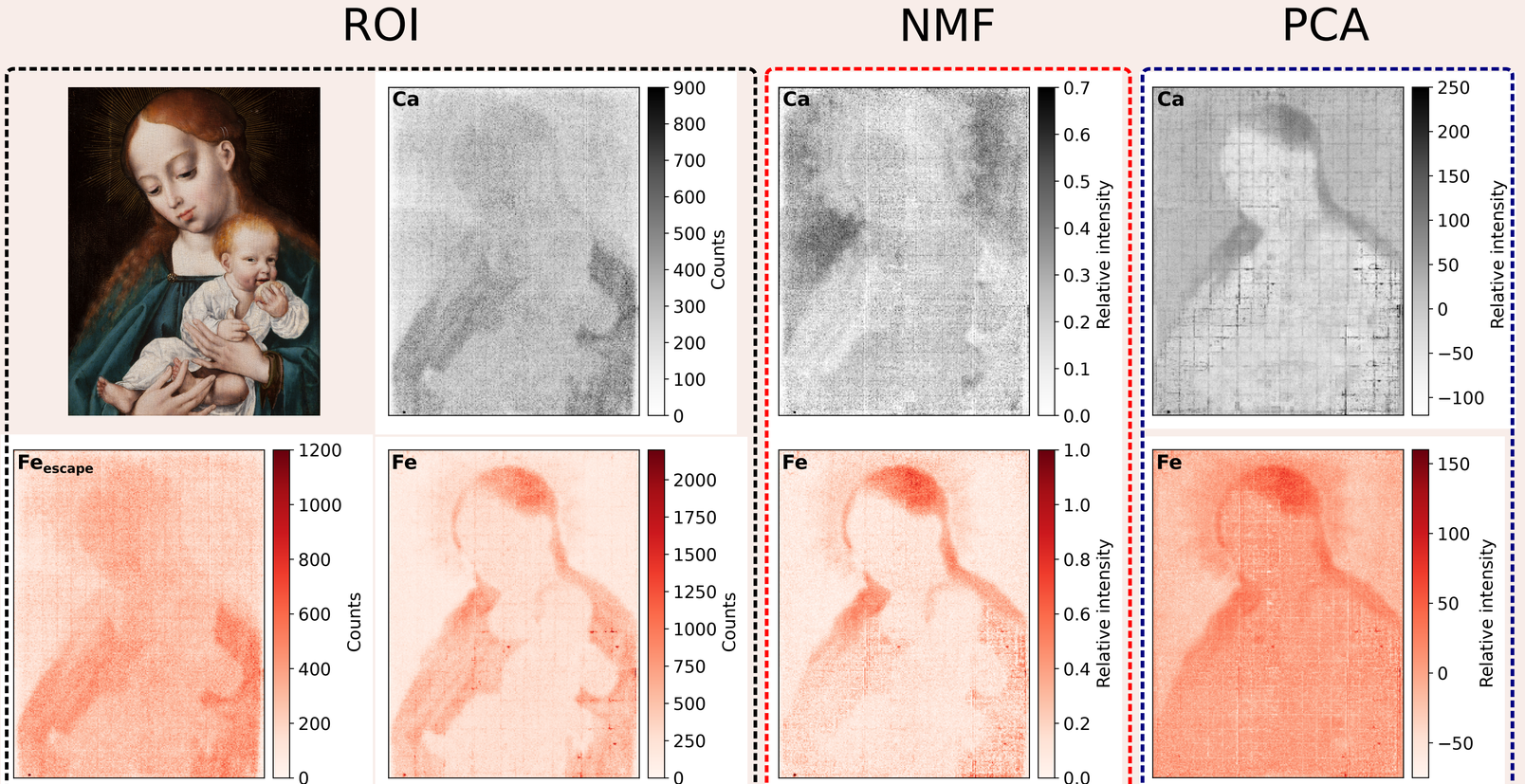

Figure 2. **Element distribution maps obtained for historical painting by ROI, NMF, and PCA methods. Joos van Cleve, Madonna and Child Eating an Apple. Courtesy of the National Museum in Krakow.**

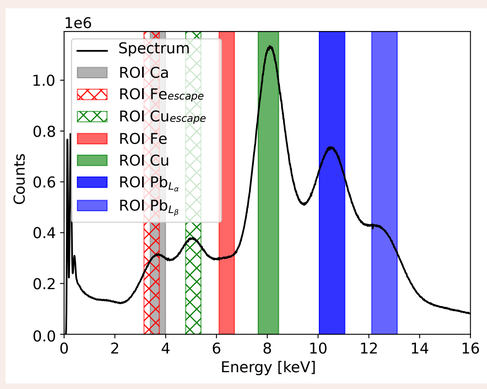

Figure 3. **Cumulative spectrum for the whole measured area with marked ROIs.**

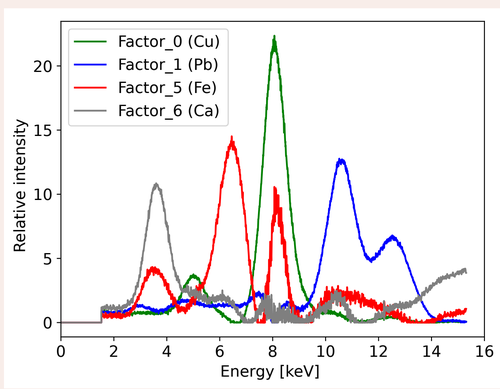

Figure 4. **Factor composition obtained from the NMF analysis.**

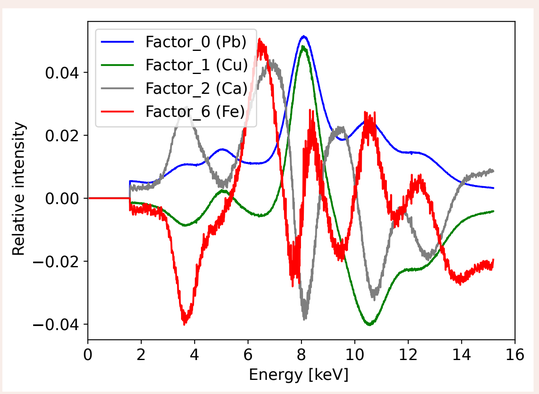

Figure 5. **Factor composition obtained from the PCA analysis.**

References

References

[1] B. Mindur et al., *Performance of a GEM detector with copper-less foils*, JINST 12 (2017) P09020.

[2] B. Mindur et al., *Investigation of Copper-Less Gas Electron Multiplier Detectors Responses to Soft X-rays*, Sensors 2020, 20, 2784.

[3] B. Łach et al., *Application of Factorisation Methods to Analysis of Elemental Distribution Maps Acquired with a Full-Field XRF Imaging Spectrometer*, Sensors 2021, 21, 7956.

[4] T. Fiutowski et al., *ARTROC – a readout ASIC for GEM-based full-field XRF imaging system*, JINST 12 (2017) C12016.

Acknowledgements

This work was supported by the Polish National Centre for Research and Development, grant no. PBS3/A9/29/2015.

†*email:* ***tomasz.fiutowski@agh.edu.pl***