

# ITERATIVE FUZZY C-MEANS ANALYSIS OF MACRO-XRF MAPPING OF “THE SCREAM” BY EDVARD MUNCH

Fauzia Albertin <sup>1</sup>, Maria Lucia Cardinali <sup>2</sup>, Laura Cartechini <sup>1</sup>, Irina Crina Anca Sandu <sup>3</sup>, Eva Storevik Tveit <sup>3</sup>, Aldo Romani <sup>1,4</sup>, Chiara Grazia <sup>1,4</sup>, Renato Pereira de Freitas <sup>1,5</sup>, Vittoria Bruni <sup>2,6</sup>, Domenico Vitulano <sup>2,6</sup>, Francesca Rosi <sup>1</sup>

(1) Istituto di Scienze e Tecnologie Chimiche “Giulio Natta” SCITEC – CNR, Via dell' Elce di Sotto 8, 06123, Perugia, Italy, [fauzia.albertin@gmail.com](mailto:fauzia.albertin@gmail.com), [laura.cartechini@cnr.it](mailto:laura.cartechini@cnr.it), [aldo.romani@cnr.it](mailto:aldo.romani@cnr.it), [francesca.rosi@cnr.it](mailto:francesca.rosi@cnr.it);

(2) Department of Basic and Applied Sciences for Engineering, Sapienza Rome University, Via Antonio Scarpa 14, 00161 Rome, Italy, [marialucia.cardinali@uniroma1.it](mailto:marialucia.cardinali@uniroma1.it), [vittoria.bruni@uniroma1.it](mailto:vittoria.bruni@uniroma1.it), [domenico.vitulano@uniroma1.it](mailto:domenico.vitulano@uniroma1.it);

(3) Paintings Conservation Section, Department of Collection Care and Management, Munch Museum, Edvard Munchs plass 1, 0194 Oslo, Norway, [irina.sandu@munchmuseet.no](mailto:irina.sandu@munchmuseet.no), [estveit@munchmuseet.no](mailto:estveit@munchmuseet.no);

(4) Centre of Excellence SMAArt and Department of Chemistry, Biology and Biotechnology, University of Perugia, Via dell' Elce di Sotto, 8, 06123, Perugia, Italy;

(5) Laboratory Federal Institute of Rio de Janeiro, Rua Buenos Aires, 256 - Bairro Centro - Rio de Janeiro/RJ, Brazil, [renato.freitas@ifrj.edu.br](mailto:renato.freitas@ifrj.edu.br);

(6) Istituto per le Applicazioni del Calcolo, IAC – CNR, Via dei Taurini, 19, 00185, Rome, Italy;

The iconic painting “The Scream” by Edvard Munch, belonging to the Munch Museum in Oslo, has been analyzed using Macro X-ray Fluorescence (MA-XRF). The artwork is characterized by a complex mixture of paints with variable thickness and shades and presents a manifold layering, with the overlapping of different brushstrokes and the mixture of the different pigments directly on the canvas – due to the use of the wet-to-wet technique. All these characteristics make the MA-XRF results complex to be read and the bare analysis of the elemental maps insufficient for a clear understanding of the paint distribution.

In order to shed light on the complex pigment mixtures and execution technique of “The Scream”, a semi-supervised classification of MA-XRF datacube through an iterative Fuzzy C-Means (FCM)-based analysis was applied. Different FCM clustering approaches were tested and the results were compared with the information obtained by univariate elaboration of the MAXRF data. Single- and double-stage FCM analysis were employed to assess correlations among dominant and minor peaks. The strengths and limitations of the proposed approach were evaluated to define a protocol of data elaboration to improve the extraction of the most relevant information compared to the simple consultation of the single or combined elemental maps.