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Energy-Dispersive Detection of X-rays with CMOS Cameras: A Machine Learning Approach

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X-ray fluorescence spectroscopy and scattering techniques are pivotal in numerous scientific fields, enabling detailed examination of structures ranging from biological tissues to advanced materials. Traditionally, Charge-Coupled Devices (CCDs) and Complementary Metal-Oxide-Semiconductor (CMOS) sensors have been employed extensively in detecting soft and tender X-rays in various X-ray experiments. These devices have been instrumental due to their high sensitivity and resolution. However, usually the X-ray intensity on the detector is integrated to increase signal to noise ratio. This mode of operation, inevitably, leads to the loss of energy information of the detected photons.
An intriguing possibility arises if individual photons can be distinguished on the detector image. This capability enables energy-dispersive operation of standard CMOS or CCDs through software-based evaluation [1], allowing for “noise-free”detection, effective suppression of background signals or even paving the way for novel methodologies like scanning-free grazing emission X-ray fluorescence. Classical algorithms currently used for this purpose primarily focus on summing up pixel intensities. However, these methods are hindered by their susceptibility to spatial overlap, also known as pile-up, which can distort the data and lead to inaccuracies in interpretation.
An alternative to these conventional methods is the use of intensity pattern fitting. While this approach can be more precise, it is considerably slower, problematic especially when dealing with large datasets typically encountered in energy-dispersive operation of CCDs and CMOS detectors.
In light of these challenges, this poster introduces a novel deep learning approach for accurately determining the position and energy of photons detected by CMOS cameras. We employ convolutional and fully-connected neural networks, trained exclusively on simulated data. The models excel in addressing pile-up issues and enable swift image evaluation.

[1] Baumann et al. J. Anal. At. Spectrom., 2018, 33, 2043-2052

Primary author: Dr BAUMANN, Jonas (Technical University of Berlin, Institute of Optics and Atomic Physics)

Co-authors: GOETZKE, Gesa (Gesa); HARTMANN, Gregor (Helmholtz-Zentrum Berlin); STAECK, Steffen (Technical University of Berlin, Institute of Optics and Atomic Physics)

Presenter: Dr BAUMANN, Jonas (Technical University of Berlin, Institute of Optics and Atomic Physics)

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