Planar Coded Aperture Reconstruction for Gamma-Imaging via Machine Learning and the TOPAS Simulation toolkit

T. Meißner[1,2], J. Hesser[1], W. Nahm[2], N. Loew[1]

[1] Mannheim Institute for Intelligent Systems in Medicine (MIISM), Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany
[2] Institute of Biomedical Engineering (IBT), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Background: Imaging of radioactive sources plays a crucial role in nuclear imaging, as well as in deposit and monitoring of nuclear waste. Coded Aperture Imaging (CAI) has been proposed decades ago to achieve a high detection rate with improved resolution. However, necessary image reconstruction methods lack the ability to adequately deal with the occurring nonlinearities.

Material and Methods: In previous work, a convolutional encoder-decoder (CED) network was trained for planar CAI reconstruction based on training data generated from a low-fidelity simulation [1]. The CED network learnt to reconstruct the source distribution in a specified distance to the gamma-camera from a given detector image.

To improve the reconstruction results, a digital duplicate of the experimental gamma-camera was implemented in TOPAS, a wrapper library for the multi-particle Monte Carlo simulation framework Geant4. It consists of a coded aperture mask, a 1mm thick 2x2 mosaicked NTHT MURA mask of Rank 31 made of Tungsten, a lead shielding, and the detector (see Figure 1). In the source plane a multitude of horizontal rectangles with random position, height, width and intensity were placed. After simulating the emission of one billion gamma-photons with a photon energy of ^{99m}Tc, all particles reaching the detector plane were stored in a phase space file. During training of the CED, a random amount of detected photons from those files were drawn and converted to an image. Together with the original source distribution, the CED network was fine-tuned. After training for 20 epochs on a total of 2000 image pairs with varying photon counts, the network was evaluated on the experimental phantom data also used in [1].

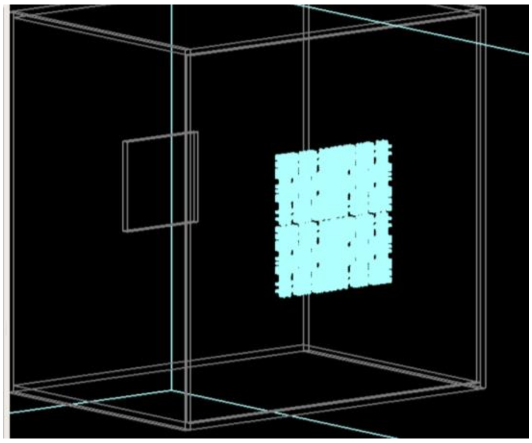

Figure 1: The simulated gamma-camera with its MURA coded aperture mask visualized in Geant4.

Preliminary results: A visible difference between detector image generated by the low-fidelity and the Geant4 simulations can be observed, which are more in accordance with the measured data. An exemplary reconstruction of the experimental data is shown in Figure 2, where the CED network produces reconstructions with more distinguishable sources and a uniform dark background. However, how such a specifically trained network performs on different types and shapes of gamma-sources remains be investigated.

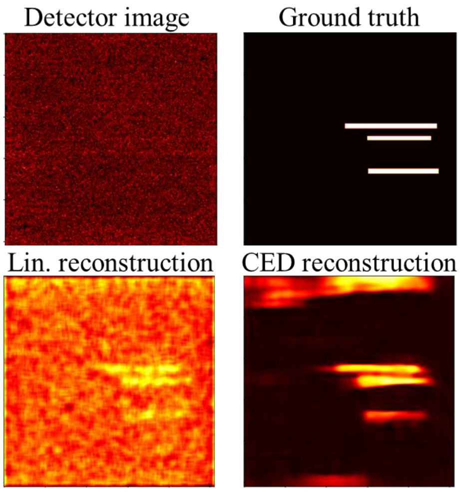

Figure 2: Detector image, the ground truth gamma-source distribution (top) and the reconstruction results by linear reconstruction and by the CED network.

[1] T. Meißner et al., arXiv, http://arxiv.org/abs/2204.14113, (2022).