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The Reconstruction Algorithm for Neutron/Gamma Imaging Detectors Based on Artificial Neural Networks

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Gamma and neutron imaging are crucial non-destructive testing techniques which have been widely used in nuclear safety, national security, materials characterization, and cultural heritage preservation. While the hit position reconstruction algorithms are key issues to improve the image fidelity and accuracy. A 2D planar neutron and gamma imaging system based on a monolithic lithium glass scintillator and a silicon photomultiplier (SiPM) array have been developed. To overcome the edge distortion of the traditional Center-of-Gravity (COG) reconstruction method, several distinct algorithms have been studied and compared, which including the Truncated COG (TCOG), the Particle Swarm-Optimized Least Squares Estimator (PSO-LSE) method and artificial neural networks (ANN) including fully connected neural network (FCNN), residual neural network (ResNet), and convolutional neural network (CNN).
The imaging performance have been evaluated using three metrics: flood image uniformity, useful field-of-view, and position linearity response. The result indicates that the ANN methods represent significant advancement over traditional reconstruction method and achieves better metrics values. These methods were used to reconstructed the images of the ‘720’ and ‘SCU’ models, and the imaging performance were quantitative evaluated by Contrast-to-Noise Ratio, Information Entropy, and Gradient Magnitude. The analysis demonstrates that the FCNN method exhibits best image quality. The spatial resolution were calculated using a knife-edge slit phantom by the modulation transfer function (MTF), and the MTF10 value of 0.45 mm have been achieved for the FCNN method. These methods have been applied on the experimental system, and validated by the flood image and pinhole image, which indicate the ANN models trained by the simulation data can be applied on the experimental data although some artifacts are introduced. This study demonstrates that ANN method significantly enhances both positioning accuracy and computational efficiency, ultimately resulting in superior quality for neutron/gamma imaging.
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Primary authors: HAN, Jifeng (Sichuan University); Mr WANG, Penghui (Sichuan University); Mr LONG, Yiyang (Sichuan University); Mr ZHAO, Chaoyang (Sichuan University); Mr YI, Chuqi (Sichuan University); Mr DUAN, Zhouhang (Sichuan University)

Presenter: HAN, Jifeng (Sichuan University)

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