

A new Neural Network Assisted CAD-based Analytical Real-Time Estimator (NACARTE) for photon dose assessment

Thursday, 30 November 2023 14:20 (20 minutes)

The decay photon fields produced by components activated during the normal operation of a nuclear plant are of particular interest for the maintenance and decommissioning functions of the plant itself, due to the threat they may pose to the health of exposed workers and to the integrity of the electronics components. For the design of the shielding for these radiation fields, extremely accurate Monte Carlo (MC) calculations are carried out using transport codes such as MCNP.

However, performing a MC calculation is a time-consuming process: this limits the opportunities for building design conceptualization, where the high accuracy of MC is not a key point. To overcome this problem, alternative methods such as the Point Kernel (PK) approach are often employed. The PK method is an analytical technique that calculates the contribution of photon radiation from a source point to a measurement point. It accomplishes this by estimating: (i) the direct contribution, modelled as a ray attenuating along the thickness of the medium between the source and the point, and (ii) the indirect contribution, by introducing a build-up factor. However, the estimation of the build-up factor remains an obstacle to obtaining a good dose estimate due to the inherent limitations of the models used such as the low spatial resolution in the prediction.

To solve this problem, we propose a novel approach that exploits deep neural networks (DNNs) to estimate build-up factors. To this end, we trained the network with thousands of MCNP simulations by varying the energy of the source, its position relative to the measurement point, and the thickness of the medium between the source and the measurement point for a single material, with the aim of achieving optimal capillarity for all possible case studies. Our method demonstrates better performance capability and spatial resolution than currently used techniques. This approach will then be implemented in a popular CAD program (SpaceClaim), providing a Neural Network Assisted CAD-based Analytical Real-Time Estimator (NACARTE) that could provide designers and engineers with immediate photon dose estimation for real-time design iterations.

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Session Classification: Posters Session

Track Classification: Physics/Engineering