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Machine Learning in Simulation of Radiation for Defence and National Security Applications

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Simulations of radiation and particle transport via Monte Carlo (MC) codes are integral to the design and safety of nuclear reactors, medical radiation systems and detector systems. A lesser known application of these simulations is in defence and national security, where such tools can provide crucial information for threat assessments and analysis of real world detector readings. These applications, however, are dynamic and demand a fast calculation time, which is incompatible with the notorious computational intensity of MC simulations.

In recent years, machine learning (ML) has gained popularity rapidly as an expedient computational alternative for classically slow problems, yet it is often limited by the availability of training data. ML techniques have some academic precedent in application to radiation and nuclear physics simulations, with limited uptake in industry thus far. In these applications, MC simulations are leveraged as a rich source of data to train models in a particular problem, such as dose map calculations, criticality calculations, or particle shower reproduction in collider detectors.

These applications demonstrate potential for further integration between MC simulation and ML networks. However, the models developed in these circumstances are specific to the geometries and parameters of the simulations they were trained on. If a different detector, or a new reactor were to be considered, these models would be ineffective without retraining and thus negate the computational benefits. Therefore a key challenge is the generalisation of ML-MC simulation techniques to a broader set of geometries and problems. We aim to evaluate the feasibility of combining the efficiency of ML with the flexibility of MC simulations to tackle more complex and demanding problems. To achieve this, a voxelisation approach is proposed where ML models are executed consecutively to propagate flux distributions through each voxel. The principles of this approach and initial findings will be discussed.

Author: STUCHBERY, James (Department of Nuclear Physics and Accelerator Applications, Research School of Physics, Australian National University.)

Co-author: SIMPSON, Edward (Australian National University)

Presenter: STUCHBERY, James (Department of Nuclear Physics and Accelerator Applications, Research School of Physics, Australian National University.)

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