Data-Driven Material Identification in Neutron Tomography Using Machine Learning

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Abstract:

Neutron tomography is a powerful non-destructive technique that is used to infer the internal material structure of a target object by analyzing its exiting neutron radiation, such as by taking many radiographic projections from different angles. This technique is uniquely able to accurately distinguish materials containing elements with lighter atomic nuclei even if they are shielded by materials with heavier nuclei. With the assistance of advanced computational simulation technology and the continual growth of artificial intelligence, significant development to this image reconstruction technique is possible.

The objective of this project is to first use Monte Carlo simulations (e.g. MCNP) to develop a realistic neutron radiography imaging platform for a target object, where significant amounts of measurement data are collected through computational simulations by varying samples in material compositions and configurations. The second step is to develop a data-driven based machine learning algorithm to identify the materials in an unknown object based on its radiographic imaging information, in which the training, validating and testing data are collected from the MCNP simulation results.

To date, the MCNP model has been fully developed, simulating a collimated beam of neutrons directed on a disk shape object composed of various materials, with neutron radiographic tallies (detectors) positioned around the object. A comprehensive set of MCNP simulation data has been generated to establish a materials library, covering a broad range of elemental compositions in nuclear applications. A representative simulation case was completed and validated through comparison with a reference model. Based on the collected simulation data, an artificial neural network (ANN) has been developed to predict the material composition of test objects and evaluated using multiple metrics. The outcomes of this project demonstrate strong potential for applications in nuclear safeguards and security.