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Adaptive response matrices for optimised mixed-field imaging

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Pinpointing the location of radiological materials has the potential to be extremely useful in many scenarios, not least of which is in nuclear decommissioning. This subject forming the focus application of this research. We present a compact and lightweight mixed-field imaging system able to produce images of radiation source terms distributed in a local environment, passively and in near real-time. A tungsten collimator produces a weighted spatial sensitivity of a liquid scintillation detector which is efficient at detecting both gamma rays and fast neutrons. Moderation of neutrons is not required, allowing the principle of back-projection to be applied to the detected neutrons as well as gamma rays. This position-sensitive detector is then rotated sequentially through two axes to collect raw image data from a minimum of 2π steradians. Radiation events are discriminated in real-time by a mixed-field analyser unit using a pulse-gradient analysis algorithm programmed into the firmware of an FPGA. Upon the collection of raw data, an algebraic reconstruction algorithm is used to reconstruct two independent images of fast-neutron and gamma-ray emitters in the surroundings. This allows these source terms to be identified and located when coupled with a corresponding overlaid optical image.

A key component in this image reconstruction is a large system matrix (containing tens of thousands of elements) which maps the sensitivity of the collimated detector to all surrounding space, for each data collection position. This system matrix is dissimilar for each radiation type due to the different interaction behaviours pronounced by the fundamental differences between gamma rays and neutrons. Further, the system matrix is also highly dependent on the energy spectrum of each radiation source; the optimal system matrix for image reconstruction will therefore be specific to each scenario, depending on the isotopes present in each case. Measuring these values experimentally to high precision is incredibly time-consuming, inconvenient for complex fields, and could invoke large costs. In response we make use of a Monte Carlo radiation transport code, validated strategically against experimental data to define these system matrices for a given energy distribution and to facilitate the most accurate image solutions. The resulting images gain superior resolution through this method, allowing an improved characterisation of radiological hazards in an environment.

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