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Numerical Reconstruction of Distributed Radioactive Sources for Decommissioning Activities

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ABSTRACT

Canada has a significant number of nuclear power plants (NPPs) that are aging and have been or could be considered for decommissioning in the near future. Decommissioning NPPs require detailed plans that rely on accurate knowledge of the radiation field in the facility environment and the risks. This presentation demonstrates a two-step technique for the real-time characterization and reconstruction of distributed radioactive sources in practical real-world environments. The final goal is to develop a system to estimate and display the predicted radioactive source and dose distribution in a real-world environment, while producing rapid refinements of the predictions as more measurements are taken.

The proposed source-reconstruction technique comprises an *a priori* step that is more computationally intensive, followed by a computationally efficient second step that can compute and refine a predicted distribution of radioactive source material that is updated in real time as measurements are taken. In the first step of this technique, a set of Monte-Carlo particle calculations are computed. A region of interest is defined where the distributed source is expected to exist. This region is discretised and a representation of the source is defined in terms of a weighted sum of polynomial basis functions. For the present work, Bernstein polynomials are used. A region where measurements may be taken is also chosen and an array of virtual detectors is defined in the computation. For each basis function from the source representation, an individual Monte-Carlo calculation is completed. The percentage of particles generated by each basis function that passes through each detector is recorded. This set of calculations can take several hours to complete, but this step can be completed prior to a worker entering a facility.

For the second step, measurements are taken in the real nuclear-engineering environment. With each new measurement, an efficient non-negative least-squares algorithm computes the weights for each source basis function that would give a source that most closely matches the real-world measurements. As more measurements are taken, this estimate is immediately refined. Solutions of the pre-computed Monte-Carlo calculations are weighted and combined to give an ever-improving estimate of the true source and radiation dose distribution.

This talk covers the mathematical details of the technique and its implementation. The technique is then applied to several scenarios that are relevant to current decommissioning efforts at the Canadian Nuclear Laboratories. Accuracy of the predicted source distribution is studied for varying number of source basis functions and measurements.