NEUP Nuclear Energy University Program
U.S. Department of Energy

Improving the computational efficiency and usability of dynamic PRA with reinforcement learning

PI: Yunfei Zhao, University of Maryland, College Park

Program: Topic Area 10 – Licensing, Safety, and Security

Collaborators:
Mohammad Modarres, University of Maryland, College Park;
Katrina Groth, University of Maryland, College Park;
Zeyun Wu, Virginia Commonwealth University;
Aaron Epiney, Idaho National Laboratory

ABSTRACT:

Probabilistic risk assessment (PRA) has been widely used in the nuclear industry to support nuclear power plant design, licensing, and other risk-informed decision-making activities. PRA techniques can be roughly classified into traditional static PRA and dynamic PRA. In static PRA, an event tree is developed manually. Dynamic PRA automates this process by integrating physics-based simulation of a nuclear plant's response to an initiating event with stochastic models of events that may affect the accident progression. Because of this integration, dynamic PRA exhibits several important advantages over traditional static PRA, for example, improved completeness and fidelity of accident progression sequences, reduced assumptions in generating accident sequences, and more coherent consideration of complex dependencies between random events in an accident. These advantages help improve the quality of PRA, which in turn results in better decision-makings in nuclear plant design and operation. A dynamic PRA analysis usually results in thousands or millions of accident sequences, each associated with physics-based simulation of the sequence. Significant efforts have been devoted to research on dynamic PRA and a variety of algorithms and tools have been developed to facilitate its application. However, there are still outstanding challenges to the wide adoption of dynamic PRA by the industry and the regulator. The primary challenge is the high computational cost associated with time-consuming physics-based simulations of a large number of sequences. Another challenge is the lack of a user-friendly approach for using the results from dynamic PRA to support risk-informed decision-making.

The proposed research aims to achieve the following objectives.

(1) The primary objective is to improve the computational efficiency of dynamic PRA. This will be achieved by developing a new algorithm for dynamic PRA based on reinforcement learning.

(2) The secondary objective is to improve the usability of dynamic PRA to improve its application to risk-informed decision-making. This will be achieved by developing a user-friendly question-answering system that can answer a variety of risk-related questions.

This project includes four major tasks to achieve the above objectives: 1) developing a new formulation for sequence generation in dynamic PRA; 2) developing a reinforcement learning approach for improving the process of sequence generation in the new formulation, therefore reducing the computational cost of dynamic PRA; 3) developing a user-friendly question-answering system that is capable of answering various risk-related questions by querying the accident sequence data generated from dynamic PRA; and 4) performing case studies to demonstrate and verify the developed new algorithm for dynamic PRA and the question-answering system.

Achieving the objectives described above will significantly improve dynamic PRA's efficiency and usability. The improved computational efficiency and usability will enable the wider application of dynamic PRA in nuclear power plant design, operation, and maintenance, which will bring both safety and cost saving benefits. The developed algorithm and question-answering system will be generic and applicable to existing light water reactors and future advanced reactors.