STATE-LEVEL NUCLEAR FUEL CYCLE SIMULATIONS FOR SAFEGUARDS APPLICATIONS

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Abstract:

A high priority in international safeguards is to support more effective processing of growing amounts and streams of data while reducing analyst workflow. However, key information such as State accountancy reports and declarations are safeguards-confidential and not available to the general R&D community for use in developing new data processing tools and methods. This dissertation modifies and develops tools for cradle-to-grave nuclear fuel cycle modeling to generate sophisticated and realistic synthetic State accounting reports.

PROPOSED CHAPTERS

Demonstration of Acquisition Pathway Analysis built on Cyclus infrastructure, ("APA")

This chapter demonstrates ability to conduct basic APA techniques using the Cyclus fuel cycle simulator.

Full fuel cycle case studies for use in fuel cycle simulator development and demonstration ("Case Studies")

Previous nuclear fuel cycle simulation literature has focused on future fuel cycle transition scenarios for individual States and regions, providing valuable technological and policy-related information. In the case of international safeguards research however, it can be important to demonstrate software capabilities on a wide landscape of potential fuel cycles. A representative set of synthetic case studies across an intentionally-diverse set of reactor designs and fuel cycle complexity will be developed.

Enhanced facility behaviors for use in Cyclus facilities ("Behaviors")

This chapter enhances nuclear fuel cycle facility and material balance area (MBA) models to incorporate more complex material movement behavior. Instead of identifying a single step in the nuclear fuel cycle and increasing agent fidelity, this work will enact a more generic set of behaviors that will be useful across the nuclear fuel cycle, each arising from a careful reflection of system behavior.

Creating synthetic fuel cycle data in the style and with the requisite information of State's accountancy reports to the IAEA ("Code 10")

A novel mechanism to create synthetic, but IAEA format and content-compatible, State-like accounting reports that include realistic types of nuclear material inventory changes and movements for the purpose of testing and developing algorithms to detect and characterize inconsistencies and disruptions that could be associated with illicit proliferation-type activities.

Demonstration and Summary

Each of the above chapters contributes to an enhanced ability to model realistic movements of nuclear material throughout the fuel cycle and will be combined in a final demonstration chapter highlighting the new tools and capabilities. APA will be conducted on each of the case studies. Several of the case studies will have a disruption introduced in one facility to interrupt their regular operational pattern, or cadence of operations. After converting simulations to the Code 10 format to match realistic State accounting reports, time series analysis and forecasting techniques will be used to demonstrate how the enhanced behaviors contribute further to the ability to develop new methods for identification of errors and unexplained patterns in State accountancy reports.

KEY WORDS

international safeguards · graph theory · nuclear fuel cycle simulators · advanced nuclear · agent-based models · acquisition pathway analysis · nuclear material accounting

COMPLETENESS

APA	●●●●○
Case studies	●●●○○
Behaviors	●○○○○
Code 10	●●●○○

COMMITTEE (DRAFT)

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KEY DATES

December 2022
Preliminary Exam

May 2023
INMM-ESARDA Joint Annual Meeting

June 2023
ANS Annual Meeting

August 2023
Defend dissertation