Nuclear Energy University Program
U.S. Department of Energy

An Optimization and Control Hub for Advanced Reactors: A Step Toward Modernizing Nuclear Engineering Education

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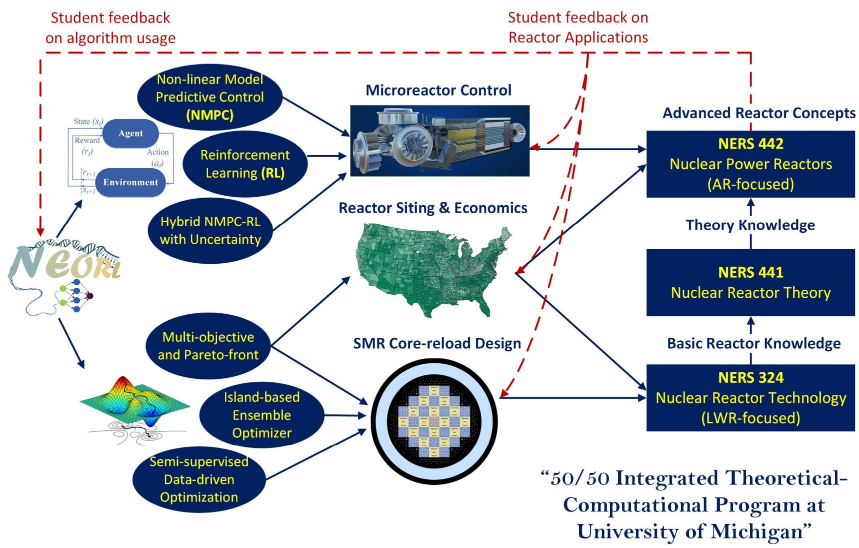
Program: Distinguished Early Career Program

ABSTRACT:

The objective of this proposal is to develop a foundational algorithmic paradigm that provides innovative optimization and control solutions to globally support DOE-NE synergistic advanced reactor (AR) programs (e.g., NEAMS, RCRD&D, ARDP). Our hub is based on the established framework NEORL (**N**euro-**E**volution **O**ptimization with **R**einforcement **L**earning), enhanced with four novel contributions.



First, we develop first-of-a-kind algorithm that features unbiased ensemble optimization with multi-objective and pareto-front support based on the island model. The island model features different algorthims (e.g., genetic algorthims, simulated annealing, particle swarm) with novel immigration rules to control the population in each island based on prior performance. This algorithm is augmented by a dynamic region-adaptive surrogate models and scalable/parallel search to support high-dimensional expensive optimization when offline surrogates or expensive reactor codes are not feasible. **Second**, by adapting non-linear model predictive controller (NMPC) and intelligent controller based on reinforcement learning (RL), we leverage a robust hybrid NMPC-RL controller that combines the best of both worlds: RL develops a model that learns from previous states, while NMPC ensures RL is fully respecting the constraints of the physical model by resolving neural network extrapolation issues. **Third**, all algorthims are demonstrated on synergistic applications to DOE-NE priorities and our educational mission on core design and reload optimization for small modular reactors, multi-objective optimization for AR siting to support coal to nuclear transition, and autonomous reactivity control for microreactors. **Fourth**, the research of this proposal culminates in an innovative teaching philosophy: *50/50 integrated theoretical-computational teaching*, where students will leverage both computational and analytical skills in a unique and cumulative computer project series with direct connections to the nuclear reactor theory topics. The reactor applications of this proposal will be projected on the course material and evaluation. Aside from the skillset the students will learn in reactor codes, programming, and algorthims - which can go with them to senior design, graduate school, or the industry - the students will provide assessment to our teaching strategies to remain sustainable. Such rigorously integrated and modern teaching philosophy will be applied for the first time into undergraduate nuclear engineering classrooms.