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Advanced Multi-Objective Optimization of Nuclear Fuel Disposal: A Comparative Study of Exact and Heuristic Algorithms

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This study addresses the critical issue of nuclear fuel disposal by proposing a comprehensive multi-objective optimization framework that balances cost, safety, environmental impact, and disposal time. Unlike traditional approaches that primarily rely on heuristic algorithms—such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Grey Wolf Optimization (GWO), Aquila Optimization Algorithm (AOA), and Simulated Annealing (SA)—this research integrates a non-linear exact solver, the Interior Point Optimizer (IPOPT), to benchmark and compare performance. Each algorithm is assessed using a unified model, with heuristic methods undergoing dedicated hyperparameter tuning to ensure fairness. IPOPT delivers the most optimal solution, excelling across all objectives due to its mathematical precision, although at the cost of higher computational time. Among heuristic algorithms, Simulated Annealing demonstrates the fastest performance with strong results, while GA and PSO perform identically, ranking second in effectiveness. AOA and GWO follow with viable but less optimal outputs. The study highlights the trade-off between computational speed and solution quality, underscoring the need for context-driven algorithm selection in real-world applications. By combining exact and heuristic methods, the research offers a robust and scalable strategy for sustainable nuclear waste management, providing valuable insights for engineers, decision-makers, and policy planners in the energy and environmental sectors.

Technical Track

Fuel Cycle and Waste Management

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