Survey of Optimization Methodologies Used in Combinatorial Nuclear Studies

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The journal articles included in this PDF were found during the literature review for the dissertation, *Adaptable Long-term Optimization of Dry Cask Storage Loading Patterns*. This survey was conducted to determine which optimization algorithms nuclear engineers have used to solve combinatorial problems. The survey was conducted using three searches:

1. Science Direct: "in-core shuffle,"
2. Science Direct: "nuclear optimization,"
3. American Nuclear Society: "optimization."

During the search, journal articles about continuous problems were ignored, and the search was conducted until 100 papers had been surveyed. This PDF categorizes the studies and includes some notes that were taken down during the search.

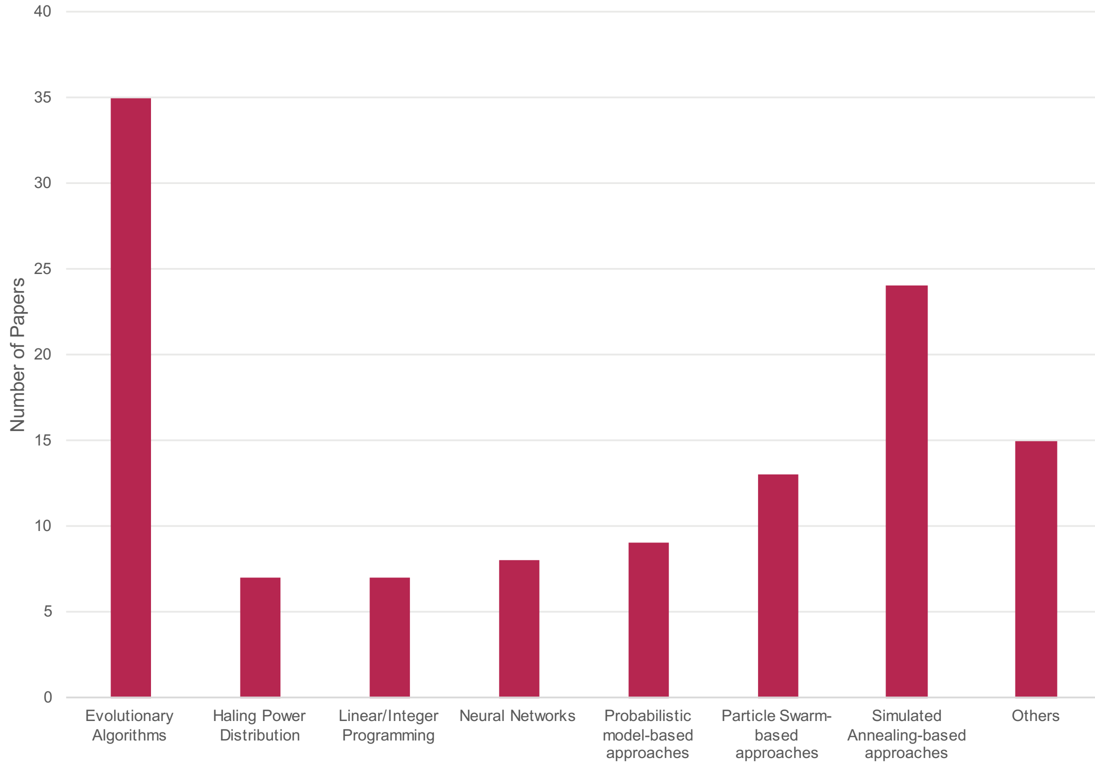

Figure 1: Distribution of optimization methodologies used for combinatorial problems in nuclear engineering. This table was created based on a survey of 100 papers: [1]–[100].

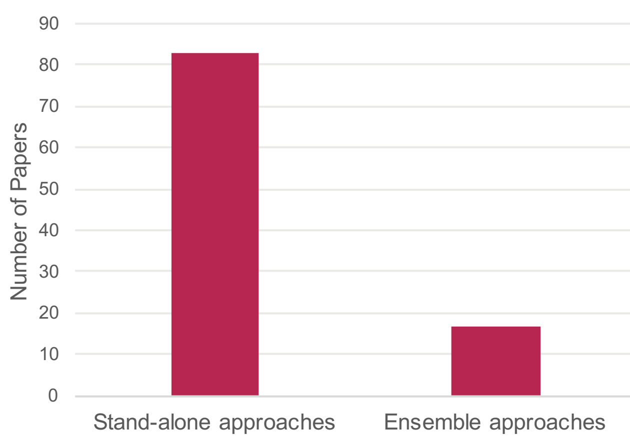

Figure 2: Comparison of stand-alone versus ensemble optimization approaches in nuclear engineering. This table was created based on a survey of 100 papers: [1]–[100]

	Pros	Cons	References
Biogeography			[85]
Genetic Algorithm	well known, widely used (MATLAB), flexible, robust, good exploration abilities	poor local search ability	[14], [15], [18], [20], [23], [26], [29], [31], [35], [36], [40], [41], [43]–[45], [48], [50], [54], [63], [64], [67], [80], [83], [90], [98]
Harmony Search Algorithms			[78], [100]
Quantum Population-Based Incremental Learning Algorithm			[70], [89]
Shuffled Frog Leaping Algorithm			[82]

Table 1: Evolutionary Algorithms

	Pros	Cons	References
Artificial Bee Colony	powerful global search ability, fewer control parameters to tune than GA or PSO	poor local search ability	[68]
Firefly Algorithm			[96]
Particle Swarm Optimization	powerful local search ability, faster than other evolutional algorithms	poor global search ability	[58], [59], [61], [73], [74], [81], [86], [90], [91]
Improved Pivot Particle Swarm Optimization	PSO + better global searching	not stated - wonder if HPA or IPPSO improves more?	[77]
Shuffled Frog Leaping Algorithm			[82]

Table 2: Particle Swarm-based Approaches

	Pros	Cons	References
Ant Colony Algorithms	efficient and versatile for combinatorial problems		[30], [52], [56], [71], [76], [87]
Cross Entropy			[92]
Quantum Population-Based Incremental Learning Algorithm			[70], [71], [89]

Table 3: Probabilistic model-based approaches

	Pros	Cons	References
Artificial Neural Networks	robust, does not need to pre-fix algorithm parameters, possibly faster	training stage may not converge, generalization ability can be a problem	[31]–[34], [38], [40], [55], [69]
Haling Power Distribution			[1], [9], [12], [37], [54], [80]
Heuristics	fast, intuitive, gives verifiable results	always an example that causes the algorithm to fail	[21], [51], [60], [72]
Linear Programming	relatively simple and scalable	the problem needs to be linear and certain, decision variables need to be independent	[4], [5], [7], [8], [16], [17]
Monte Carlo Integer Programming	able to handle a large number of decision variables, does not require everything to be linearized, determines not only optimal solution but also near-optimum family of solutions	not stated	[6]
Simulated Annealing	able to optimize over large search spaces and to handle many local optima; able to handle non-linear objectives and constraints combined with discrete variables	if cooling schedule too fast, solution may be trapped in local minimum, too slow, low computational efficiency	[10], [11], [13], [22], [24], [25], [28], [33], [39], [49], [53], [55], [57], [65], [66], [75], [79], [84], [86], [88], [94], [95], [97], [99]
The Tabu Search			[19], [27], [45], [46], [87], [93]

Table 4: Optimization Methodologies

Nuclear articles with hybrid methods:

- Ant Colony + Tabu Hybrid: [87]
- Artificial Neural Network + Genetic Algorithm: [31], [40]
- Artificial Neural Network + Simulated Annealing: [33], [55]
- Genetic Algorithm + Haling Power Distribution: [54], [80]
- Genetic Algorithm + Simulated Annealing: [90]
- Genetic Algorithm + Tabu Search: [45]
- Particle Swarm Optimization + Heuristics: [61]
- Particle Swarm Optimization + Local Search: Liu and Cai incorporate the M. Clerc pivot local search method with PSO to improve the local search ability for a fuel loading pattern optimization study in [77].
- Particle Swarm Optimization + Simulated Annealing: [86]
- Quantum Population-Based Incremental Learning Algorithm: [70], [89]
- Quantum + Ant Colony: [71]
- Simulated Annealing + Branch & Bound: [97]
- Shuffled Frog Leaping: Ensemble of particle swarm optimization and the shuffled complex evolution technique in [82].

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