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Uncertain bilevel knapsack problem based on an improved binary wolf pack algorithm

Key words: Bilevel knapsack problem; Uncertainty; Improved binary wolf pack algorithm

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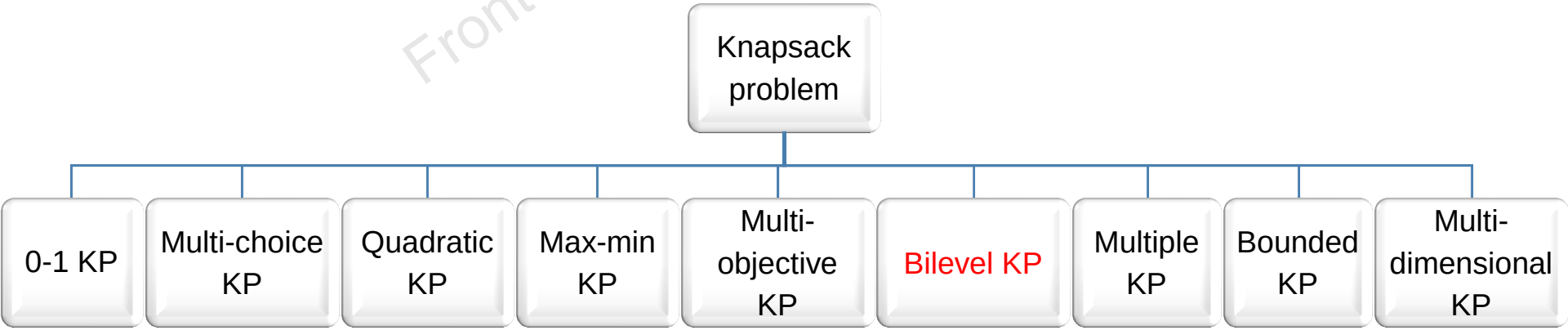
Knapsack problem

- Knapsack problem (KP) is a well-known combinatorial optimization problem with wide applications and various types.

Domain	Application
Industry	Material distribution
Economy	Capital budget
Finance	Investment decision
Logistics	Cargo loading optimization
Computer	Distributed system
Information security	Construction of public key cryptosystem



Motivation

- Bilevel KP (BKP) parameters are often indeterminate, particularly for issues related to combat, such as an armament transportation problem.
- Many researchers solve the uncertain BKP (UBKP) using probability theory, while the effective probability distributions of many real-world problems cannot be obtained due to lack of sufficient sample data.
- Fuzzy theory cannot effectively deal with the indeterministic reliability, and the related fuzzy KP also has certain limitations.

UBKP model

- To handle UBKPs, an uncertain solution can be found by applying the $\mathcal{P}_E$ Nash equilibrium and $\mathcal{P}_E$ Stackelberg–Nash equilibrium to transform UBKP to a corresponding equivalent deterministic model.
- BKP involves two decision-makers interacting hierarchically. A leader (responsible for a subset of variables) must explicitly consider the reaction of a follower (responsible for another subset of variables) in its optimization process.

Improved binary wolf pack algorithm

- The evolutionary improved binary wolf pack algorithm (IBWPA) is a swarm intelligence based optimization algorithm, comprising one regulation, two operators, and three intelligent behaviors.

Swarm intelligence




Wolf pack algorithm


Leader wolf


Scout wolf


Ferocious wolf


Cooperative hunting

Scouting behavior

Intelligent hunting behavior

Upgrading

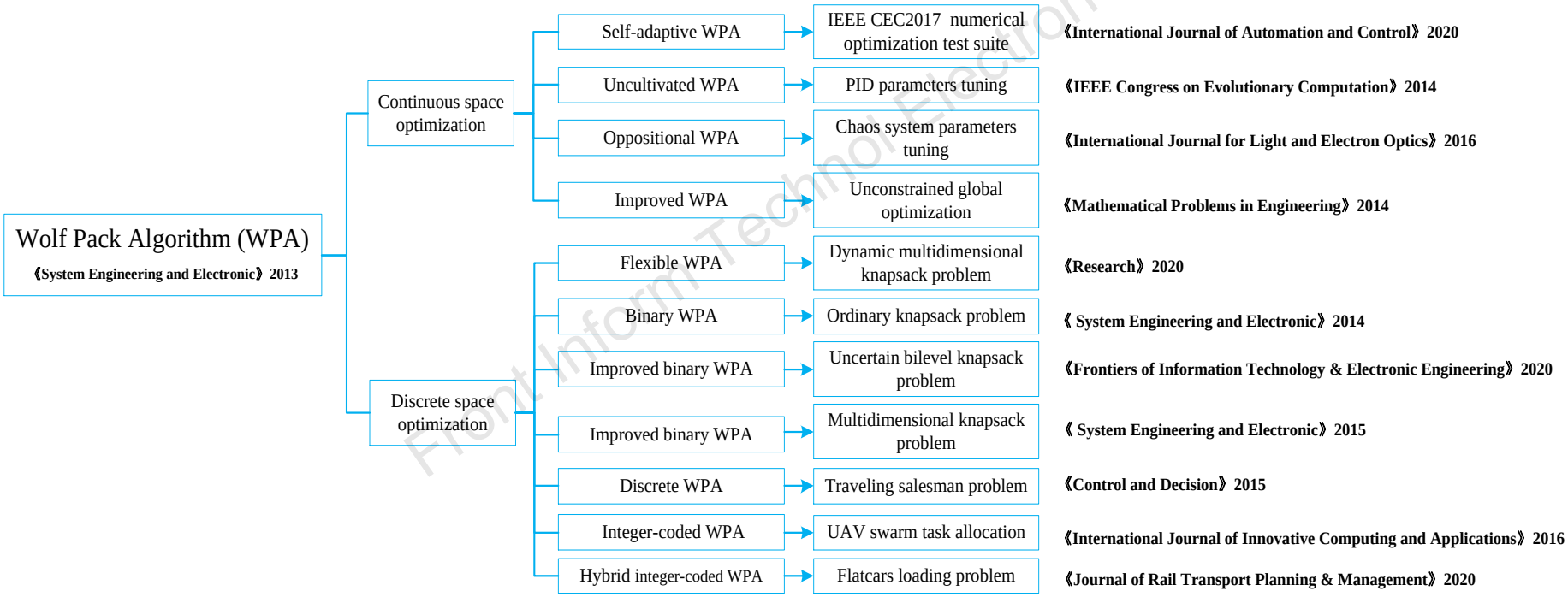
Wolf leader regulation

Invert operator

Move operator

Applications of IBWPA

- Wolf pack algorithm (WPA) has been applied in many real-world problems and a series of derivative versions have been developed.



Move operator

- Move operator preserves the same part of items between the wolf leader and the artificial wolf to retain the elite advantages and to increase population diversity.

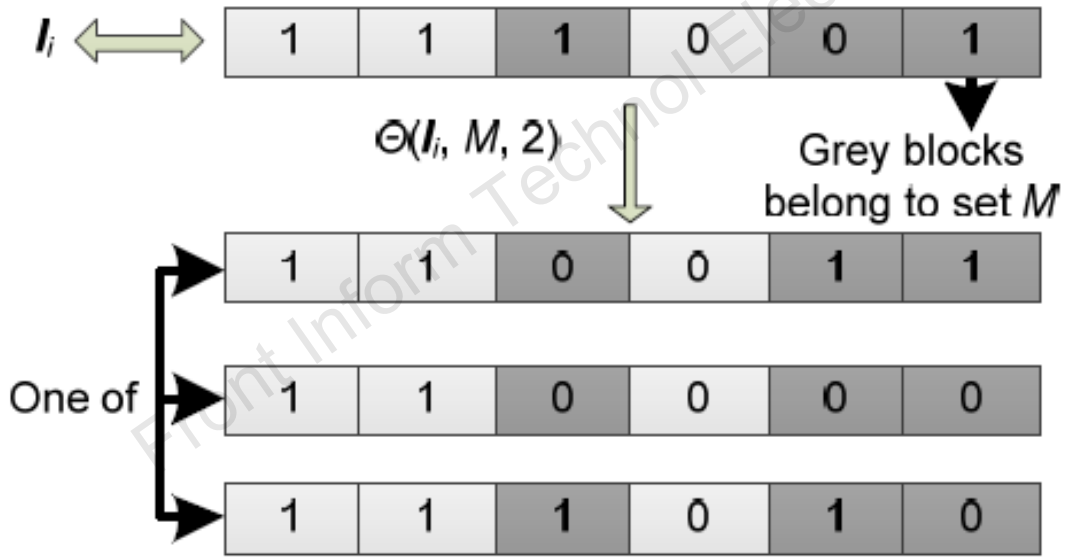


Fig. 1 Illustration of the move operator

Simulations

- To demonstrate the effectiveness of IBWPA in solving UBKP, simulations on classic KP benchmarks were performed because UBKP is a special type of KP.

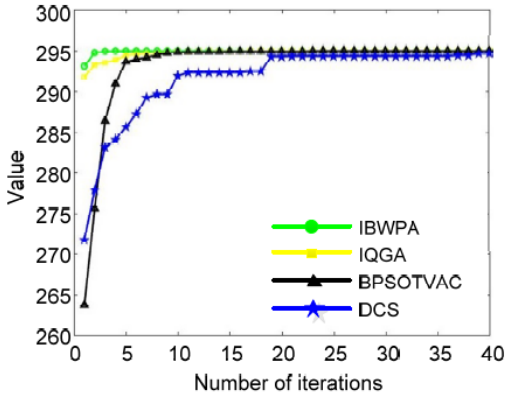


Fig. 3 Average convergence curves for KP1

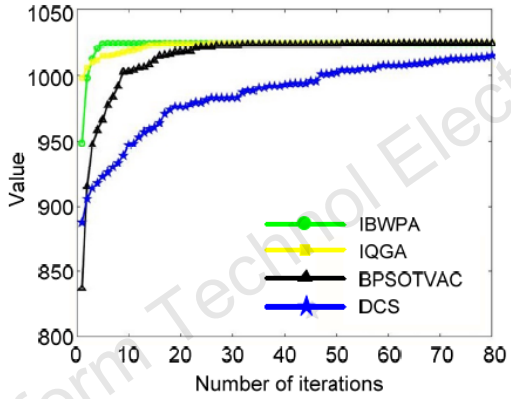


Fig. 4 Average convergence curves for KP2

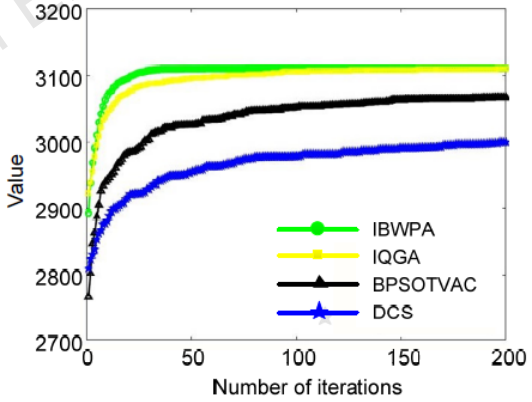


Fig. 5 Average convergence curves for KP3

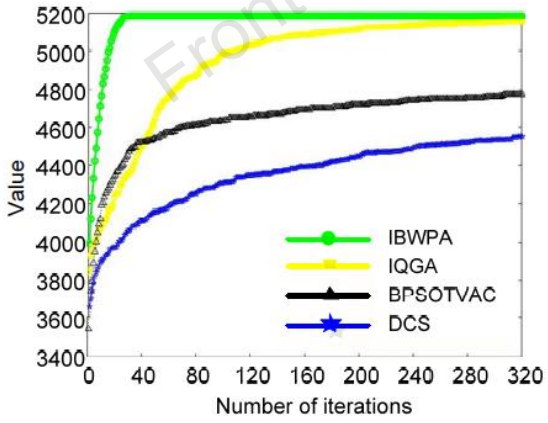


Fig. 6 Average convergence curves for KP4

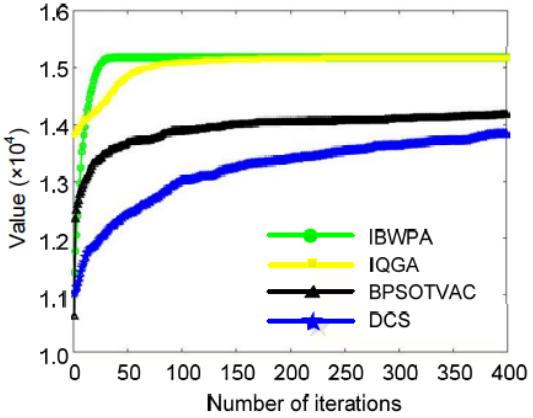


Fig. 7 Average convergence curves for KP5

Applications

- An armament transportation example with uncertain parameters is applied as a case study. Several armaments and combat groups must be transported by airplane. The frontier commander must maximize the combat capacity in the frontier, and the transportation commander attempts to guarantee safety in the transportation process.

Conclusions

- A UBKP model which is a special type of BKP with uncertain variables is proposed.
- An uncertain solution has been developed to transform UBKP to an equivalent deterministic model.
- Computational efficiency has been improved by the proposed evolutionary IBWPA.
- The performance of IBWPA was much better than that of the algorithms compared for several typical knapsack problem benchmark tests.
- IBWPA has been applied to an armament transportation problem under uncertain parameters.

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