Jian DONG, Xia YUAN, Meng WANG, 2022. Competitive binary multi-objective grey wolf optimizer for fast compact antenna topology optimization. *Frontiers of Information Technology & Electronic Engineering*, 23(9):1390-1406. https://doi.org/10.1631/FITEE.2100420

Competitive binary multi-objective grey wolf optimizer for fast compact antenna topology optimization

Key words: Antenna topology optimization; Multi-objective grey wolf optimizer; High-dimensional mixed variables; Fast design

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Motivation

- The methods based on binary evolutionary algorithms (EAs) no longer restrict the initial antenna structure. However, they face the challenge that the electromagnetic (EM) simulation cost tremendously increases with the number of iterations and populations in EAs. Therefore, the problem of high computational cost remains.
- There are difficulties in the method of combining neural networks with antenna design. In antenna design, the cost of acquiring training datasets through physical testing or EM simulation software is very high. Moreover, the size of the dataset of the training neural network is often related to the antenna variables to be optimized, and the more variables there are, the larger dataset is needed. The problem of high computational cost still exists.

Main idea

A competitive binary multi-objective grey wolf optimizer (CBMOGWO) is proposed for fast compact antenna topology optimization:

- introducing the competition mechanism to divide the population into several parts, so as to reduce the difficulty of calculation (Aldhafeeri and Rahmat-Samii, 2019);
- replacing the linear convergence factor with the cosine oscillation convergence factor to achieve a better balance between exploration and exploitation;
- designing a compact high-isolation dual-band multiple-input multiple-output (MIMO) antenna topology with high-dimensional mixed variables.

In our example, CBMOGWO obtains the Pareto solution sets with only half the time of the original binary multi-objective grey wolf optimizer (BMOGWO) and binary multi-objective particle swarm optimization (BMOPSO), which indicates that the proposed CBMOGWO method not only has good optimization performance but also greatly improves the design efficiency.

Method

Competitive binary MOGWO

1. Antenna topology optimization:

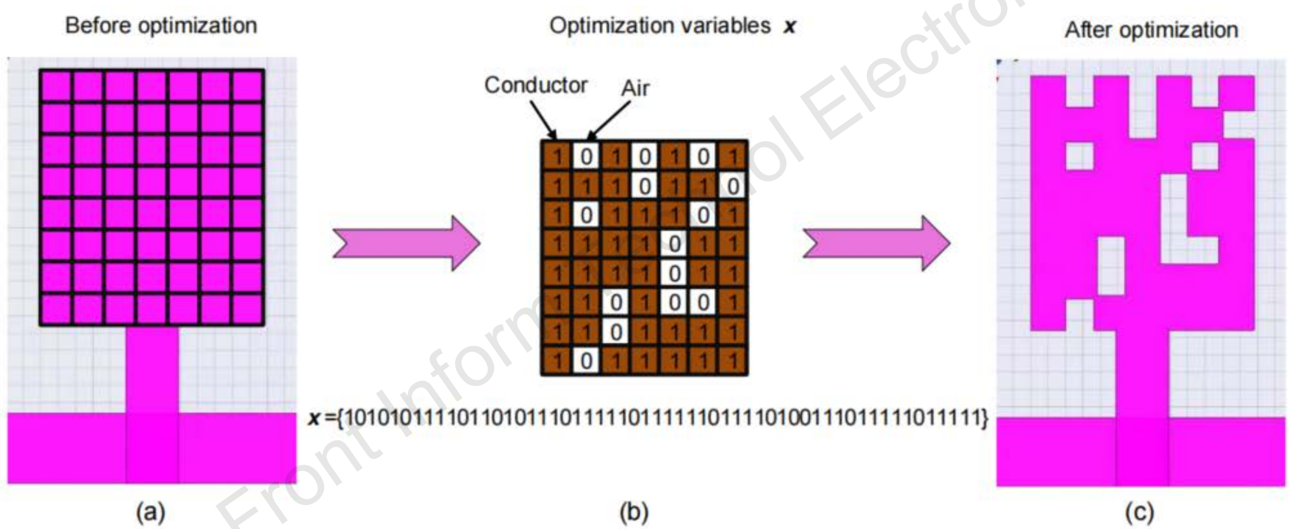
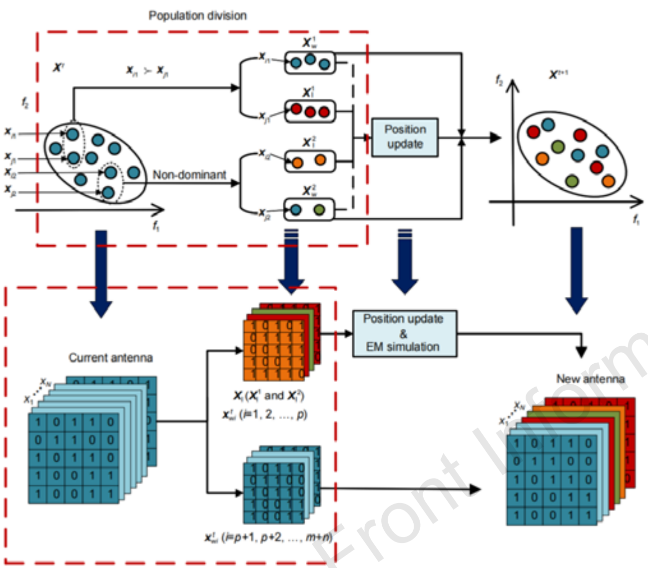


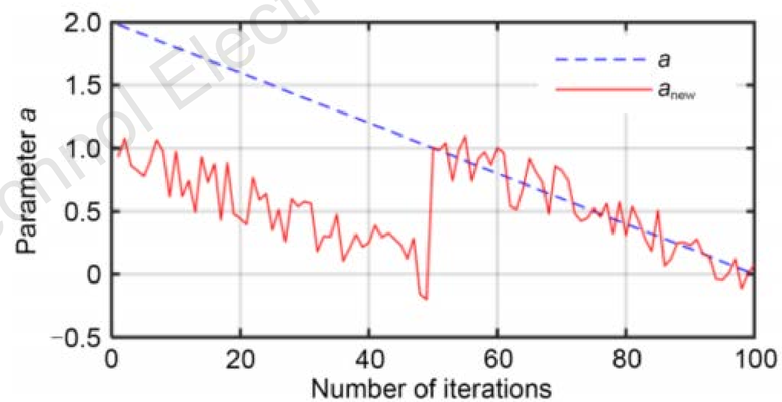
Fig. 1 Diagram of antenna topology optimization: (a) antenna structure before optimization; (b) mapping between the physical antenna structure and binary vector x; (c) antenna structure after optimization

Method (Cont'd)

Competitive binary MOGWO

2. Population competition:





3. Convergence factor of cosine oscillation

Major results

1. Part of the results in the numerical experiments

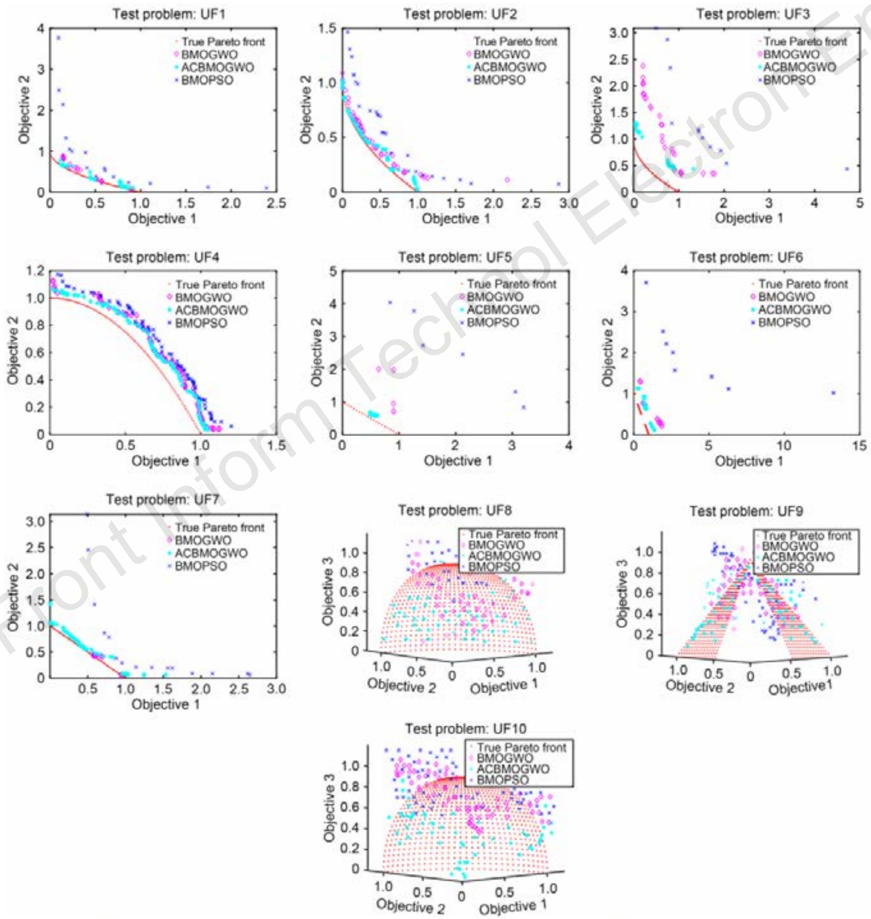


Fig. 4 Obtained Pareto optimal solutions by BMOPSO, BMOGWO, and CBMOGWO for UF1 to UF10

Major results (Cont'd)

1. Results of antenna design.

Table 4 Comparison of optimal performance and computational cost between different antenna optimizations

Optimization aproach	Average HV	Number of EM simulations	Average CPU time Total (h)	Average CPU time Relative (%)
BMOPSO	0.9145	930	7.98	96.84
BMOGWO	0.9500	930	8.24	100.00
CBMOGWO	0.9996	570	4.92	59.71

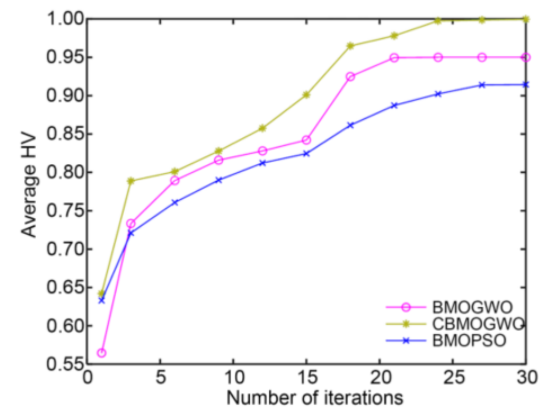


Fig. 11 Evolution of the average HV value in antenna topology optimization

Conclusions

1. In this paper, an efficient and cost-effective algorithm, named CBMOGWO, is proposed for antenna topology optimization. First, the competitive mechanism is used to reduce the number of calls to EM simulation to reduce calculation costs. Then, we introduce the cosine oscillation function into the linear convergence factor of the original BMOGWO to balance exploration and exploitation.

2. The high efficiency of our method in antenna topology optimization is validated with the design example of a compact dual-band MIMO antenna with high-dimensional mixed design variables and multiple objectives. CBMOGWO requires only about 60% of the time consumed by the traditional BMOGWO and BMOPSO, which shows that our method is highly adaptable even for complex design problems.

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