

Performance Analysis of Some Modern Metaheuristics for The Design and Optimization of Electromagnetic Devices

Houssem R.E.H. Boucekara¹, Mostafa K. Smail^{2,3}, Muhammad S. Javaid⁴ and Abdelhak Goudjil²

¹Department of Electrical engineering, University of Hafr Al Batin, Hafr Al Batin 31991, Saudi Arabia, rboucekara@uhb.edu.sa

²IPSA - Institut Polytechnique des Sciences Avancées, Ivry-sur-Seine, France, mostafa-kamel.smail@ipsa.fr
abdelhak.goudjil@ipsa.fr

³GeePs - Group of Electrical Engineering Paris, UMR CNRS 8507, CentraleSupélec, Université Paris-Saclay, Sorbonne University, Gif sur Yvette, France, mostafa-kamel.smail@centralesupelec.fr

⁴Department of Electrical and Electronic Engineering, Imperial College London, London, UK. m.javaidd19@imperial.ac.uk

In recent decades, we have observed a rapid development of new metaheuristic algorithms due to many factors. One of these factors is the increasing complexity of real-world problems, which make them very challenging for traditional algorithms. Another important factor is the advancements in hardware and parallel processing which have significantly enhanced the computational capabilities of modern computers, enabling the implementation of more sophisticated algorithms. The aim of this paper is to evaluate and compare the performance of several modern metaheuristic algorithms for the optimal design of electromagnetic devices. This comparative study analyzes each algorithm, highlighting their strengths and limitations. By systematically examining their performance, we seek to provide insights into which methods are most suitable for addressing the complexities of electromagnetic device optimal design.

Index Terms— Electromagnetic Devices, Modern Metaheuristics, Optimization, Performance Analysis.

I. INTRODUCTION

DESIGN and optimization of electromagnetic devices using metaheuristics have been effectively explored for the past decades. Many examples can be found in the literature either using analytical models or Finite Element Models (FEMs). A survey of some algorithms will be given in the extended version of this work. Furthermore, in recent years, several high-performance metaheuristics have been developed driven by advancements in the computational capabilities of modern computers. The aim of this paper is to compare the performance of newly developed metaheuristics for the optimal design of electromagnetic devices.

II. TESTED METAHEURISTICS

A. Modern Metaheuristics

The selected algorithms are briefly described below.

1. Ali Baba and the Forty Thieves Optimization (AFT)

The AFT algorithm, developed in 2021, is inspired by the famous tale of *Ali Baba and the Forty Thieves*. The authors used the clever strategies employed by the thieves to find Ali Baba, as well as the intelligent tactics used by Ali Baba's maid to save him, as the basis for developing the AFT [1].

2. Golden Eagle Optimizer (GEO)

The GEO algorithm, developed in 2021, is inspired by the golden eagle's hunting behavior. Eagles use a spiral trajectory to search for prey, transitioning smoothly from cruising to attacking. They balance exploration (searching for prey) and exploitation (attacking), adjusting their strategies based on energy efficiency and prey quality [2].

3. Hunger Games Search (HGS)

The HGS algorithm, developed in 2021, is inspired by animals' competitive behaviors driven by hunger. It models the decision-making process animals undergo in their search for

food, balancing exploration, defense, and competition to ensure survival [3].

4. Rat Swarm Optimizer (RSO)

The RSO algorithm, developed in 2021, is inspired by the chasing and fighting behaviors of rats. Rats are socially intelligent and territorial animals, exhibiting aggressive behavior when competing for resources [4].

5. Tiki-Taka Algorithm (TA)

The TA algorithm, developed in 2021, is inspired by the tiki-taka football style, known for its short passing, precise player positioning, and control of possession. Just as in tiki-taka, where players work together fluidly to build attacks, the TA emphasizes strategic movements and coordination to optimize the problem in hand [5].

6. Pelican Optimization Algorithm (POA)

The POA algorithm, developed in 2022, is inspired by the natural hunting behavior of pelicans, where the search agents are pelicans that are actively searching for food sources [6].

7. Tasmanian Devil Optimization (TDO)

The TDO algorithm, developed in 2022, is inspired by the natural feeding behavior of the Tasmanian devil. It mimics two primary feeding strategies of the Tasmanian devil: one where it feeds on carrion (dead animals) when available, and another where it actively hunts and attacks live prey [7].

8. White Shark Optimizer (WSO)

The WSO algorithm, developed in 2022, is inspired by the dynamic hunting behavior and unique sensory abilities of white sharks. Specifically, the WSO is inspired by the sharks' method of ambush hunting, their streamlined swimming capabilities, and their keen senses of hearing and smell, which they use to detect prey from a distance [8].

9. Zebra Optimization Algorithm (ZOA)

The ZOA algorithm, developed in 2022, is inspired by the natural behaviors of zebras, specifically their foraging strategy, where a pioneer zebra guides the herd to food sources, and their

defense strategy, where they escape predators in a zigzag pattern to confuse them [9].

10. Artificial Hummingbird Algorithm (AHA)

The AHA algorithm, developed in 2022, is inspired by the hummingbird's flight abilities, memory, and foraging strategies. Their exceptional memory allows them to efficiently locate food sources, while their unique flight skills, including hovering and precise movement in any direction, are key elements in developing the algorithm [10].

B. Legacy algorithms

Selected modern metaheuristics have been compared against well-known optimization algorithms: Biogeography-Based Optimization (BBO), Differential Evolution (DE), Gaining sharing knowledge-based algorithm (GSK), Grey Wolf optimizer (GWO), JAYA, Particle Swarm Optimization (PSO), Salp Swarm Algorithm (SSA), Teaching Learning based optimization algorithm (TLBO) and the Most Valuable Player Algorithm (MVPA).

III. SELECTED BENCHMARKS

To assess the performance of the selected algorithms, we selected the benchmarks summarized in TABLE I. In the extended version of this paper, many other benchmarks will also be tested.

TABLE I
ELECTROMAGNETIC DEVICES SELECTED BENCHMARKS

Benchmark	Model	Design variables	Objective function
Brushless DC Wheel Motor Benchmark (BLDC)	Analytical	5	Maximize the efficiency of the motor
Loney solenoid	Analytical	2	Uniformize the magnetic flux density in a controlled region
TEAM workshop 22	Analytical	8	The weighted average of two objectives; energy and stray field requirements
Safety transformer	Analytical	9	Minimize the total mass of iron and copper materials
Loudspeaker	FEM	7	Maximize the magnetic flux density through the air gap

IV. RESULTS AND DISCUSSION

The modern metaheuristics presented in section II.A, along with the well-known metaheuristics presented in Section II.B, have been tested across the set of selected benchmarks presented in Section III. The results obtained are summarized in TABLE II. It is important to note that the comparative method used in this paper is the same as the one employed in CEC 2022 for evaluating the performance of various algorithms. The following comments can be made from TABLE II:

- The best overall algorithm is the TDO, it has a total score of 17446.
- It has been ranked 1 based on Score 1 and 4 based on Score 2.
- The best algorithm based on Score 1 is TDO whilst the best algorithm based on Score 2 is DE. The best legacy algorithm is DE as it has a score of 16729 and it is ranked 3.

- The TDO and WSO algorithms are the only two modern algorithms that are better than all selected legacy algorithms.

TABLE II
COMPARISON OF DIFFERENT ALGORITHMS

Algorithm	Score 1	Score 2	Total Score	Rank
TDO	9328	8118	17446	1
WSO	7423	9659	17082	2
DE	6694	10035	16729	3
MVPA	7311.5	8073	15384.5	4
GSK	5137	9636	14773	5
AFT	6880	7196	14076	6
AHA	7130	6414	13544	7
POA	8008	5387	13395	8
HGS	6071	6518	12589	9
ZOA	8256	4276	12532	10
PSO	7153.5	4990	12143.5	11
TTA	2930	5212	8142	12
BBO	3058	3556	6614	13
GWO	3655	2795	6450	14
GEO	3552	1329	4881	15
SSA	2326	1713	4039	16
RSO	627	697	1324	17
TLBO	85	21	106	18

V. CONCLUSION

In this paper, a comparative study between recently developed metaheuristics for the design of electromagnetic devices is performed. This study shows that the top three algorithms are TDO, WSO and DE, respectively. More details and results will be given in the extend version of this paper.

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