University Badji-Mokhtar . Annaba
Faculty of Technology
ILC_M2

BUTTERFLY OPTIMIZATION ALGORITHM

Presented by
Sadat Litissia

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Introduction

Optimization is a key challenge in many fields. Some problems—like scheduling or path planning—are too complex for traditional methods. This led to the creation of nature-inspired algorithms that mimic smart behaviors found in nature to find good solutions.

The Butterfly Optimization Algorithm (BOA) is a recent metaheuristic inspired by how butterflies use fragrant pheromones to communicate and locate resources. BOA models this behavior to perform efficient global search and local exploration, making it useful for a wide range of real-world optimization tasks.

Biological Aspects

Butterflies interact using scents (pheromones).
The intensity of the scent depends on:

- environment conditions,
- the butterfly's energy,
- the distance from others.

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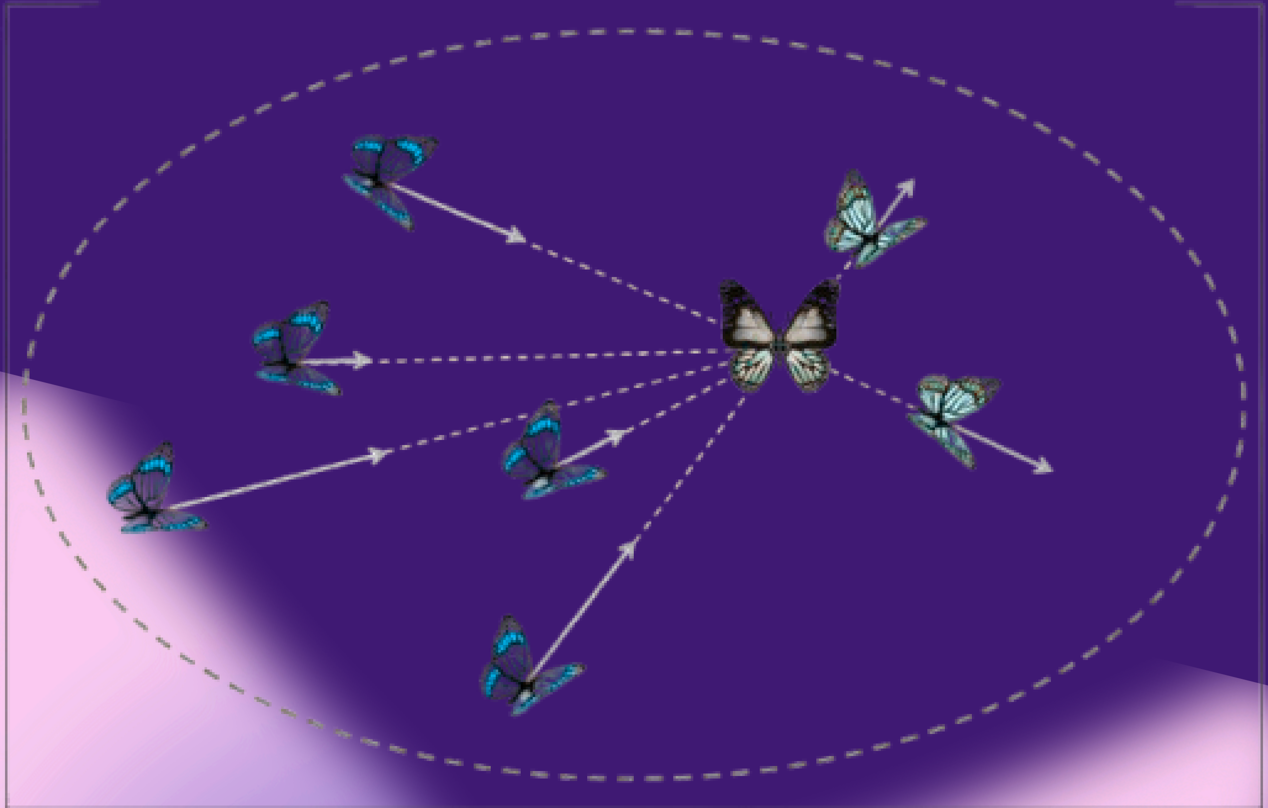
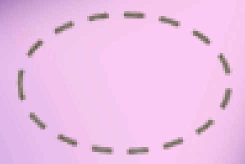
Butterflies exhibit two behaviors:

- moving toward stronger scents,
- or performing random movements when no strong scent is detected.

Artificial Metaphor Behind BOA



Symbol				
Meaning	Those butterflies (${}^{t}\mathbf{X}_j$) located in worse locations than the virtual butterfly $f({}^{t}\mathbf{X}^{V}) < f({}^{t}\mathbf{X}_j)$	Those butterflies (${}^{t}\mathbf{X}_k$) stand in the better locations than the virtual butterfly $f({}^{t}\mathbf{X}^{V}) > f({}^{t}\mathbf{X}_k)$	Virtual butterfly	A sample region of the search space

In the Butterfly Optimization Algorithm (BOA), the biological behavior of butterflies is translated into an artificial search mechanism:

- Each butterfly represents a candidate solution.
- The fragrance emitted by a butterfly corresponds to the fitness value of that solution.
- Moving toward the best butterfly models exploitation, where the algorithm intensively searches around promising areas.
- Random movement represents exploration, allowing the search to escape local optima and discover new regions of the solution space.

A switching probability p controls the balance between global and local search. At each iteration, the algorithm decides based on p whether butterflies perform a global exploration step or a local exploitation step.

Application Domains

BOA has been successfully applied in:

- structural optimization,
- feature selection in machine learning,
- neural network training,
- UAV path planning and robotics,
- energy systems,
- scheduling and routing,
- biomedical signal processing.

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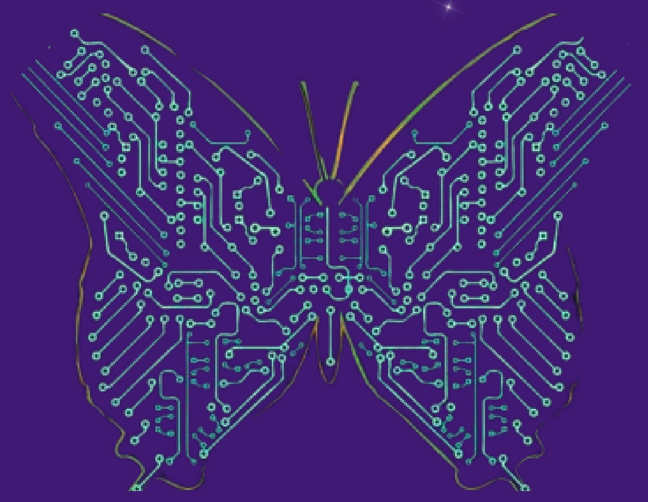
Existing BOA-Based Algorithms



Several variants have been developed to improve performance:

- Original BOA
- Chaotic BOA
- Improved BOA (IBOA)
- Quantum-based BOA
- Adaptive BOA

Details of the Basic Algorithm

Fragrance computation

$f = c \times I^a$

where I is the fitness, and c and a are sensory parameters

Global search

Butterfly moves toward the best solution.

Local search

Butterfly moves randomly using the positions of two neighboring butterflies.

Example – UAV Trajectory Planning

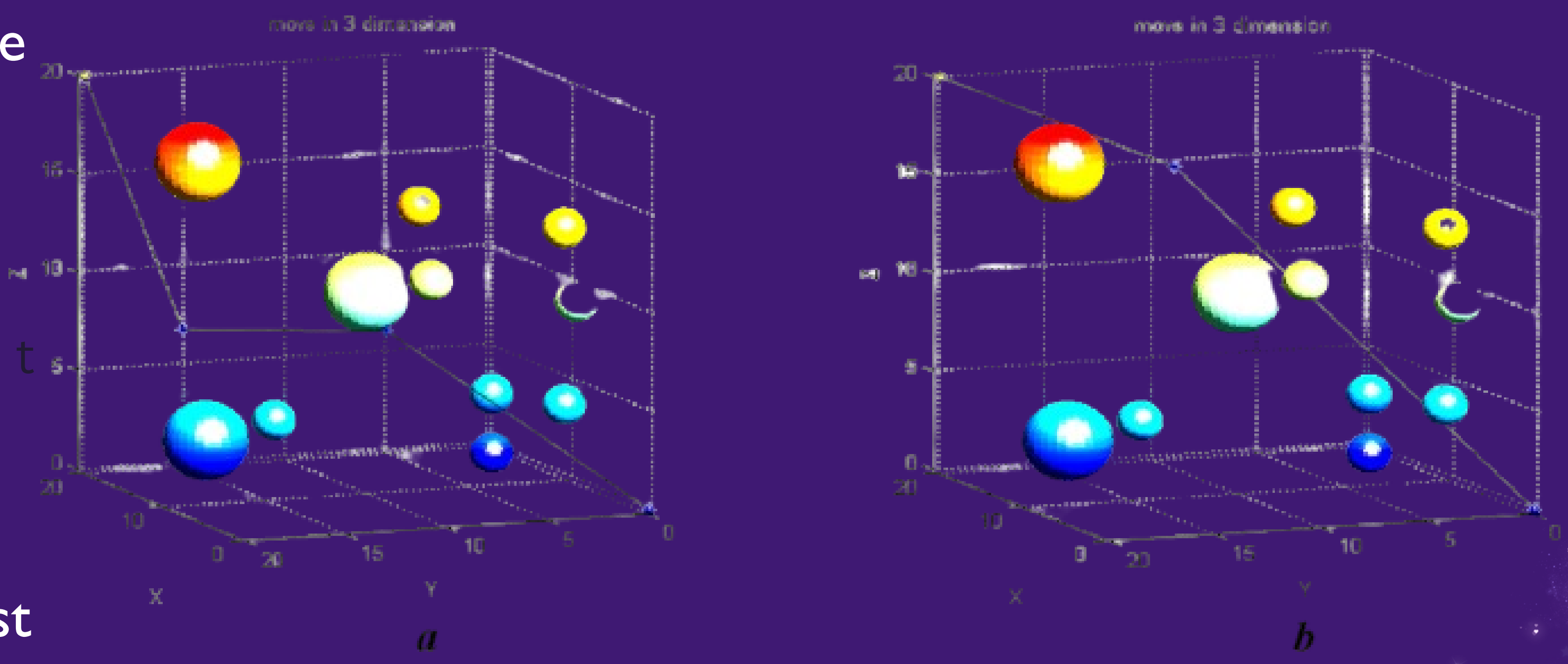
UAV (drone) path planning aims to compute the best route that:

- avoids obstacles,
- minimizes total flight distance,
- reduces energy consumption.

In this problem, BOA evaluates possible flight paths as candidate solutions.

Experiments show that BOA achieves the lowest path cost in the best-case scenario, outperforming:

- Ant Colony Optimization (ACO),
- Particle Swarm Optimization (PSO).



Strengths & Weaknesses

Weaknesses

• May prematurely converge if the switching probability is not well tuned.
• Local search may be weak in complex landscapes.
• Performance strongly depends on parameter settings (a, c, p).
• Sometimes less stable than older, more mature algorithms (GA, PSO) for noisy problems.
• No built-in memory mechanism like in PSO (particles remember best positions).

Strengths

• Simple and easy to implement, with few parameters.
• Fast convergence due to the strong global movement mechanism.
• Good balance between exploration and exploitation.
• Works well in high-dimensional spaces (feature selection, path planning).
• Flexible and easily hybridized with other algorithms (PSO–BOA, CNN–BOA, GA–BOA).

Conclusion

The Butterfly Optimization Algorithm is a fast and flexible method for solving complex optimization problems.
It performs well in tasks like feature selection and UAV path planning. Despite some limits such as parameter sensitivity, BOA and its improved versions remain powerful and promising tools for future intelligent optimization.

THANK YOU