Nature Inspired Soft Computing
(23CS3202)

CO – 4

- Whale Optimization Algorithm (WOA),
- Brainstorm Optimization Algorithm (BOA).

AIM OF THE SESSION

- To familiarize students with the concepts of Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA).
- To make students apply above algorithms on a real world problem

INSTRUCTIONAL OBJECTIVES

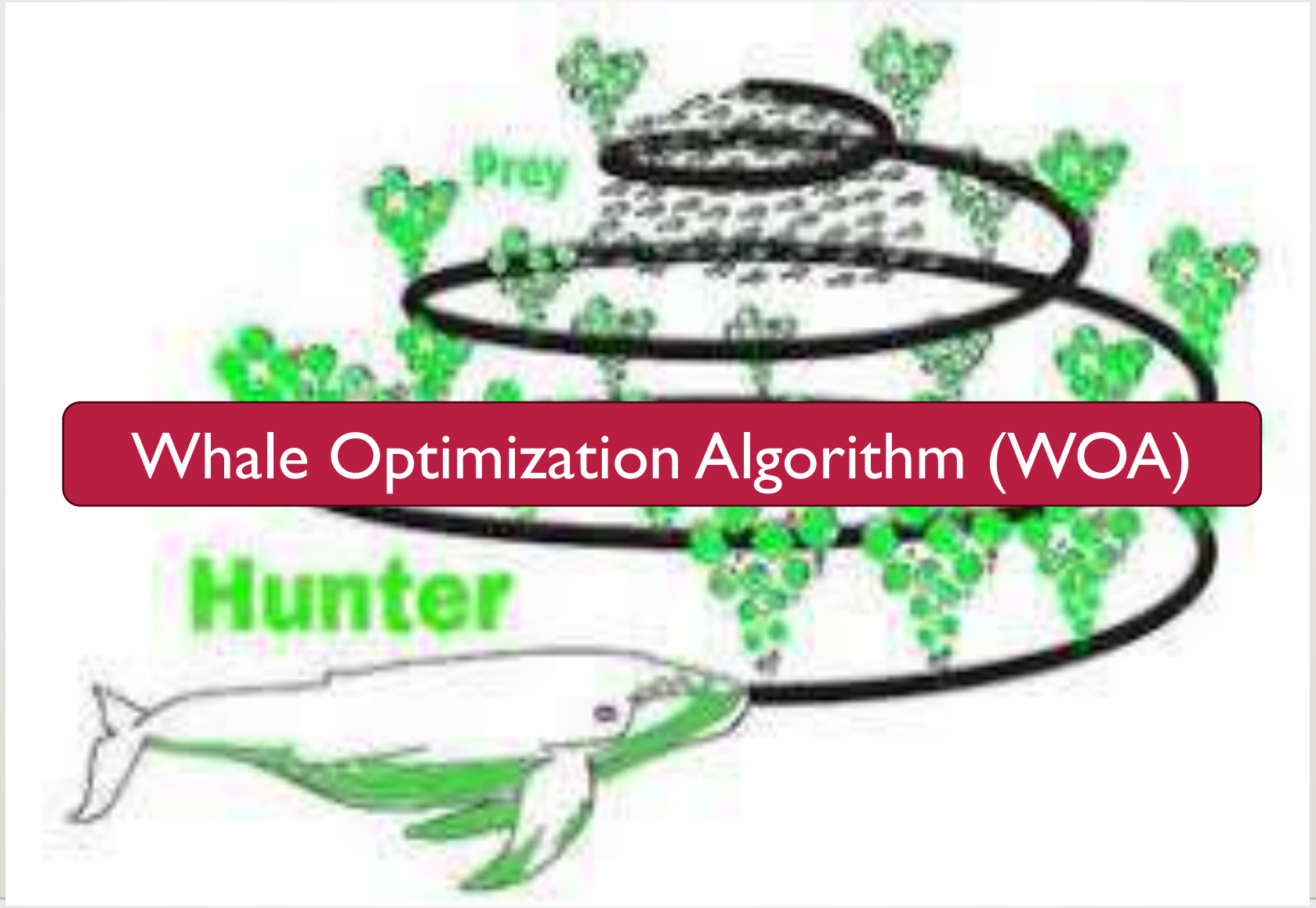
This unit is designed to:

1. Demonstrate Firefly Algorithm Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA) and its concepts.
2. Describe the nature and features of Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA).
3. List out the techniques of Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA).
4. Demonstrate the process of Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA).

LEARNING OUTCOMES

At the end of this unit, you should be able to:

1. Define the functions of Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA)..
2. Summarize the techniques used for building the Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA).
3. Describe ways to build the Whale Optimization Algorithm (WOA), Brainstorm Optimization Algorithm (BOA)..



Whale Optimization Algorithm (WOA)

Whale Optimization Algorithm (WOA)

INTRODUCTION

The **Whale Optimization Algorithm (WOA)** is a metaheuristic optimization algorithm inspired by the **hunting behavior of humpback whales**. Proposed by **Mirjalili and Lewis in 2016**, it mimics the **bubble-net feeding strategy** of whales to solve optimization problems. WOA is a population-based technique that balances **exploration** and **exploitation** to find the best solutions.

- **Key Inspiration from Whale Behavior:**
- Humpback whales use a **bubble-net feeding mechanism** to encircle and trap prey.
- Whales **spiral towards their prey**, which is mathematically modeled in the algorithm.
- The method of **encircling and shrinking** improves the search efficiency.

Whale Optimization Algorithm (WOA)

ALGORITHM OVERVIEW

The **Whale Optimization Algorithm** mimics the cooperative hunting behavior of whales using three key mechanisms:

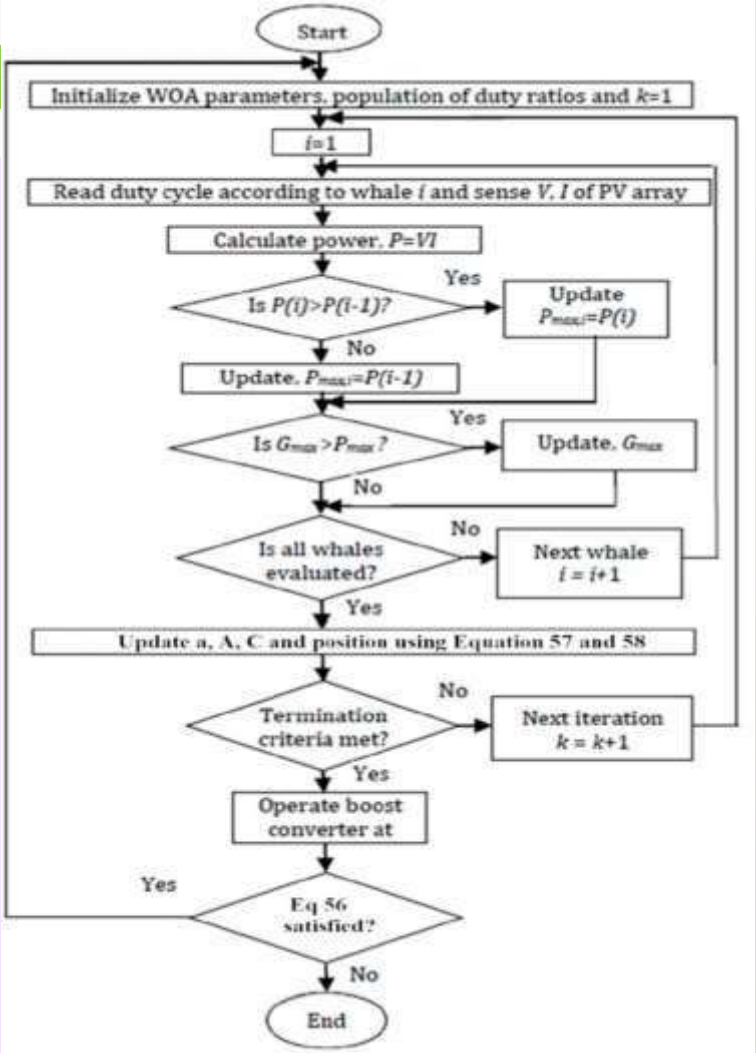
1. **Encircling Prey** – Whales identify the best solution and move towards it.
2. **Bubble-Net Attacking Method (Exploitation)** – Mimics the spiral movement of whales while hunting.
3. **Search for Prey (Exploration)** – Encourages diversification to avoid local optima.

- **Key Features of WOA:**
- Uses **exploration and exploitation phases** effectively.
- Works well for both **continuous and discrete optimization problems**.
- Requires **minimal parameter tuning**, making it simple and efficient.

Whale Optimization Algorithm (WOA)

STEPS OF WOA ALGORITHM

1. Initialize whale population (random solutions in the search space).
2. Evaluate the fitness of each whale based on the objective function.
3. Identify the best solution (prey).
4. Encircling prey (Exploitation phase): Adjust position towards the best solution.
5. Bubble-net hunting (Local search & Spiral updating): Use a probability-based approach (50%) to decide between encircling and spiral movement.
6. Search for prey (Exploration phase): Introduce randomness to explore new solutions.
7. Update positions and check termination criteria. If convergence or maximum iterations reached, stop; otherwise, repeat.



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Whale Optimization Algorithm (WOA)

MATHEMATICAL REPRESENTATION

1. **Encircling Prey (Exploitation Phase):**

$$\vec{D} = |\vec{C} \cdot \vec{X}^*(t) - \vec{X}(t)|$$

$$\vec{X}(t+1) = \vec{X}^*(t) - \vec{A} \cdot \vec{D}$$

where:

- $\vec{X}^*(t)$ is the best current solution.
- $\vec{X}(t)$ is the whale's position.
- $\vec{A}$ and $\vec{C}$ are coefficient vectors controlling search dynamics.

2. **Bubble-Net Attacking Strategy:**

- A **spiral motion** is used for local search:

$$\vec{X}(t+1) = \vec{D} \cdot e^{bl} \cdot \cos(2\pi l) + \vec{X}^*(t)$$

where b is a constant defining the spiral shape, and l is a random number in [-1,1].

Whale Optimization Algorithm (WOA)

MATHEMATICAL REPRESENTATION

3. **Search for Prey (Exploration Phase):**

- Introduces randomness to improve global search:

$$\vec{D} = |\vec{C} \cdot \vec{X_{rand}} - \vec{X}|$$

$$\vec{X}(t+1) = \vec{X_{rand}} - \vec{A} \cdot \vec{D}$$

where, X_{rand} is a randomly selected whale.

Whale Optimization Algorithm (WOA)

TYPES OF WOA

Several modifications of WOA exist to improve performance:

1. **Standard WOA** – The original algorithm by Mirjalili and Lewis (2016).
2. **Improved WOA (IWOA)** – Enhances convergence by adjusting parameter settings dynamically.
3. **Hybrid WOA** – Combines WOA with other algorithms (e.g., PSO, Genetic Algorithm) for better efficiency.
4. **Binary WOA** – Adapts WOA for discrete and combinatorial optimization problems.

Whale Optimization Algorithm (WOA)

APPLICATIONS OF WOA

WOA is widely applied in:

- **Engineering Design Optimization** (mechanical, electrical, civil design problems)
- **Image Processing** (segmentation, feature selection)
- **Wireless Sensor Networks (WSN) Optimization**
- **Medical Diagnosis & Bioinformatics**
- **Scheduling & Resource Allocation**
- **Machine Learning & Deep Learning Parameter Tuning**
- **Financial Market Prediction & Portfolio Optimization**

ADVANTAGES OF WOA

✓ **Fast Convergence:** Efficient search mechanisms improve optimization speed.

✓ **Simple to Implement:** Requires fewer parameters than other metaheuristic algorithms.

✓ **Effective Exploration and Exploitation:** Ensures good balance for finding optimal solutions.

✓ **Scalability:** Works well for both small and large-scale problems.

Whale Optimization Algorithm (WOA)

CHALLENGES OF WOA

✕ Premature Convergence: May get stuck in local optima in complex problems.

✕ Parameter Sensitivity: Performance depends on the selection of coefficients (A, C, b).

✕ Comparative Performance: In some cases, GA or PSO may outperform WOA.

✕ Lack of Diversity in Some Cases: Requires hybridization with other techniques for better results.

Whale Optimization Algorithm (WOA)

REFERENCES

- ***Mirjalili, S., & Lewis, A. (2016).*** *"The Whale Optimization Algorithm." Advances in Engineering Software.*
- *Research papers on metaheuristic optimization techniques.*
- *Books on swarm intelligence and bio-inspired algorithms.*

Brainstorm Optimization Algorithm (BOA).

Brainstorm Optimization Algorithm (BOA).

INTRODUCTION

The **Brainstorm Optimization Algorithm (BOA)** is a **metaheuristic optimization algorithm** inspired by **human brainstorming processes**. Proposed by **Shi in 2011**, it mimics the **divergent and convergent thinking** involved in problem-solving and idea generation.

- **Key Inspiration from Brainstorming:**
- Humans generate multiple ideas before selecting the best one.
- Ideas evolve through combination, mutation, and refinement.
- The balance between exploration (divergent thinking) and exploitation (convergent thinking) is crucial for finding optimal solutions.

Brainstorm Optimization Algorithm (BOA).

ALGORITHM OVERVIEW

The **Brainstorm Optimization Algorithm** simulates the idea-generation process in groups and follows these main steps:

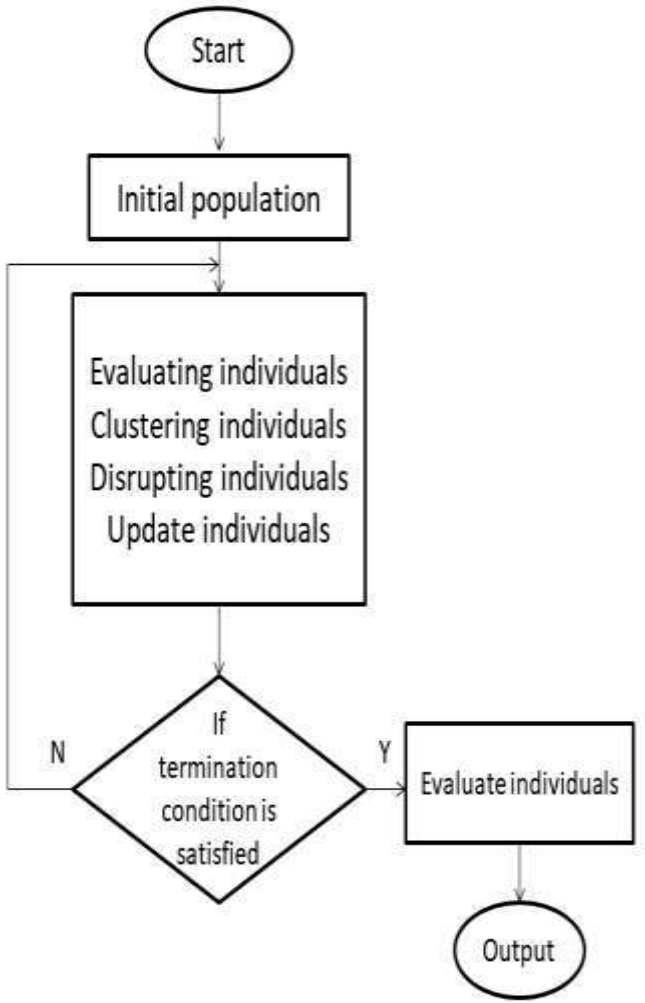
1. **Clustering-based Idea Generation** – Solutions are grouped into clusters.
2. **Mutation & Evolution** – New ideas are created by mutating existing ones.
3. **Selection Mechanism** – The best solutions are retained for further iteration.

- **Key Features of BOA:**
- Uses **clustering mechanisms** to generate diverse solutions.
- Simulates **human brainstorming** for optimization.
- Works well for **both continuous and discrete problems**.
- Requires **minimal parameter tuning** and is computationally efficient.

Brainstorm Optimization Algorithm (BOA).

STEPS OF BOA ALGORITHM

1. **Initialize Population** – Generate initial random solutions.
2. **Cluster Solutions** – Group similar solutions into clusters.
3. **Generate New Solutions:**
    1. Select representatives from each cluster.
    2. Apply **mutation and recombination** to create new ideas.
4. **Evaluate Fitness of New Solutions.**
5. **Select Best Solutions:**
    1. Retain the top-performing solutions.
6. **Repeat until Convergence** – Continue iterations until termination criteria are met.



Brainstorm Optimization Algorithm (BOA).

MATHEMATICAL REPRESENTATION

1. **Clustering-based Idea Generation:**

$$X_{new} = X_i + \lambda \cdot (X_j - X_k)$$

where:

- X_i, X_j, X_k are selected individuals from different clusters.
- λ is a random factor controlling the extent of mutation.

2. **Mutation & Evolution:**

$$X_{mutated} = X_{best} + \alpha \cdot (X_{random} - X_{best})$$

where X_{best} is the best solution, and α is a mutation factor.

3. **Selection Mechanism:**

- The newly generated solutions are evaluated, and the best ones are selected for the next iteration.

Brainstorm Optimization Algorithm (BOA).

TYPES OF BOA ALGORITHM

Several variants of BOA have been developed:

- Standard BOA – The original algorithm proposed by Shi (2011).
- Improved BOA (IBOA) – Enhances diversity by using dynamic clustering.
- Hybrid BOA – Integrates BOA with other metaheuristics (e.g., PSO, GA) for improved performance.
- Binary BOA – Adapts BOA for discrete optimization problems.

Brainstorm Optimization Algorithm (BOA).

APPLICATIONS OF BOA

BOA has been successfully applied in various fields:

- **Engineering Design Optimization**
- **Machine Learning Parameter Tuning**
- **Image Processing & Feature Selection**
- **Scheduling & Resource Allocation**
- **Financial Market Analysis**
- **Wireless Sensor Networks Optimization**

Brainstorm Optimization Algorithm (BOA).

ADVANTAGES OF BOA

✓ **Balanced Exploration & Exploitation:** Ensures better search performance.

✓ **Robust to Local Minima:** Uses clustering to escape local optima.

✓ **Adaptive Learning Mechanism:** Simulates human brainstorming for better results.

✓ **Versatile & Scalable:** Works for diverse optimization problems.

Brainstorm Optimization Algorithm (BOA).

CHALLENGES OF BOA

✕ **Computational Complexity:** Clustering and mutation operations add computational overhead.

✕ **Parameter Sensitivity:** Performance depends on selecting the right clustering and mutation parameters.

✕ **Comparative Performance:** Other metaheuristics may outperform BOA in certain problems.

✕ **Lack of Standardization:** Different variations exist, making implementation inconsistent.

Brainstorm Optimization Algorithm (BOA).

REFERENCES

- ***Shi, Y. (2011).*** *"Brainstorm Optimization Algorithm." IEEE International Conference on Intelligent Systems and Knowledge Engineering.*
- *Research papers on metaheuristic optimization techniques.*
- *Books on swarm intelligence and bio-inspired algorithms.*

Terminal Questions .

1. Explain how WOA mimics the hunting behavior of humpback whales.
2. Describe the mathematical model of the encircling mechanism in WOA and its significance.
3. How does the bubble-net attacking strategy contribute to WOA's exploitation capability?
4. Compare the exploration and exploitation phases in WOA with another optimization algorithm like PSO or GA.
5. What factors influence the convergence speed of WOA, and how can it be improved?
6. Suggest a real-world optimization problem where WOA can outperform other metaheuristics.
7. Modify the basic WOA by introducing a mutation operator and explain how it may impact the algorithm's performance.
8. Analyze the impact of randomization in WOA's search strategy and how it balances exploration and exploitation.

Terminal Questions .

9. Who proposed the Brainstorm Optimization Algorithm (BOA) and in which year?
10. What is the inspiration behind BOA?
11. How does the clustering mechanism work in BOA?
12. Describe the role of mutation in BOA.
13. What are the key parameters affecting BOA's performance?
14. How does BOA balance exploration and exploitation?
15. Compare BOA with Particle Swarm Optimization (PSO) in terms of efficiency.
16. Suggest a real-world problem where BOA can be effectively applied.

THANK YOU