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FALCON OPTIMIZATION ALGORITHM

Implemetation on traveling salseman problem

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1 INTRODUCTION

Overview of TSP

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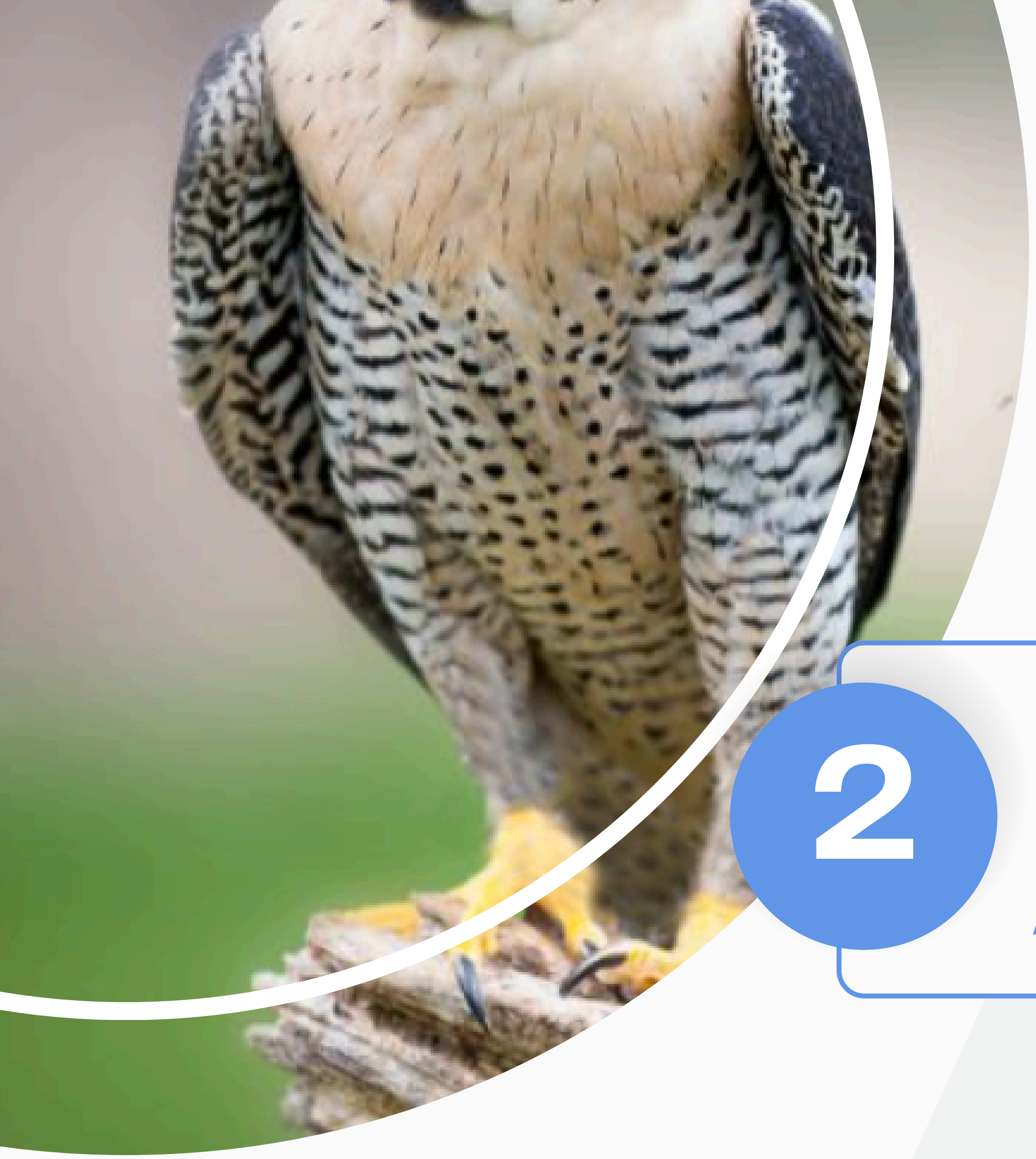
The Traveling Salesman Problem (TSP) stands as one of the most enduring and well-known combinatorial optimization challenges in the realms of computer science, operations research, and mathematics.

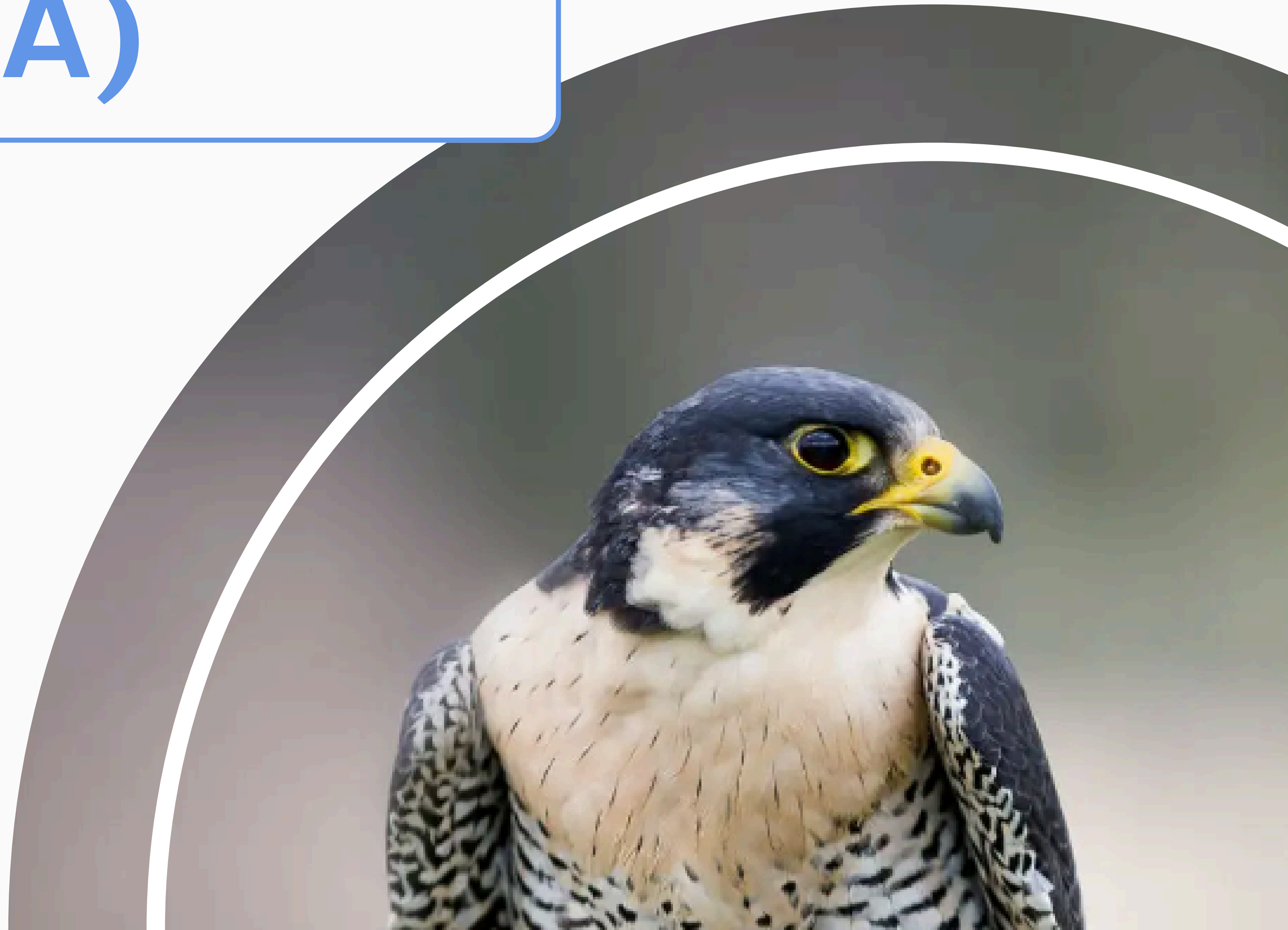
The TSP involves determining the shortest possible route that visits a set of cities exactly once and returns to the origin city.

The problem is how to find a minimal route passing from all the nodes. for example, if you take path one from {A, B, C, D, E,A} and the path two that is {A, B, C, E, D, A} you have passed all the cities, but the two paths are diffrent in the name of the distance .

TSP focus on reducing cost of building construction engineering and also reduces material wastages, through its principals of finding the minimum cost path of the salesman.



2 Falcon Optimization Algorithm (FOA)



FALCON OPTIMIZATION ALGORITHM

Overview of FOA

Metaheuristics are nature-inspired algorithms for obtaining comparative solutions to any computationally difficult optimization problems. The swarming behaviors of animals (including ant, pigeon, fish, bee, etc.) have been used in metaheuristics .

In the proposed metaheuristic algorithm depends on the falcon's behavior of hunting. The falcon optimization algorithm (FOA) is the reliable and robust algorithm of stochastic population-based problems that requires arrangements from several parameters to its three-stage action settlement.

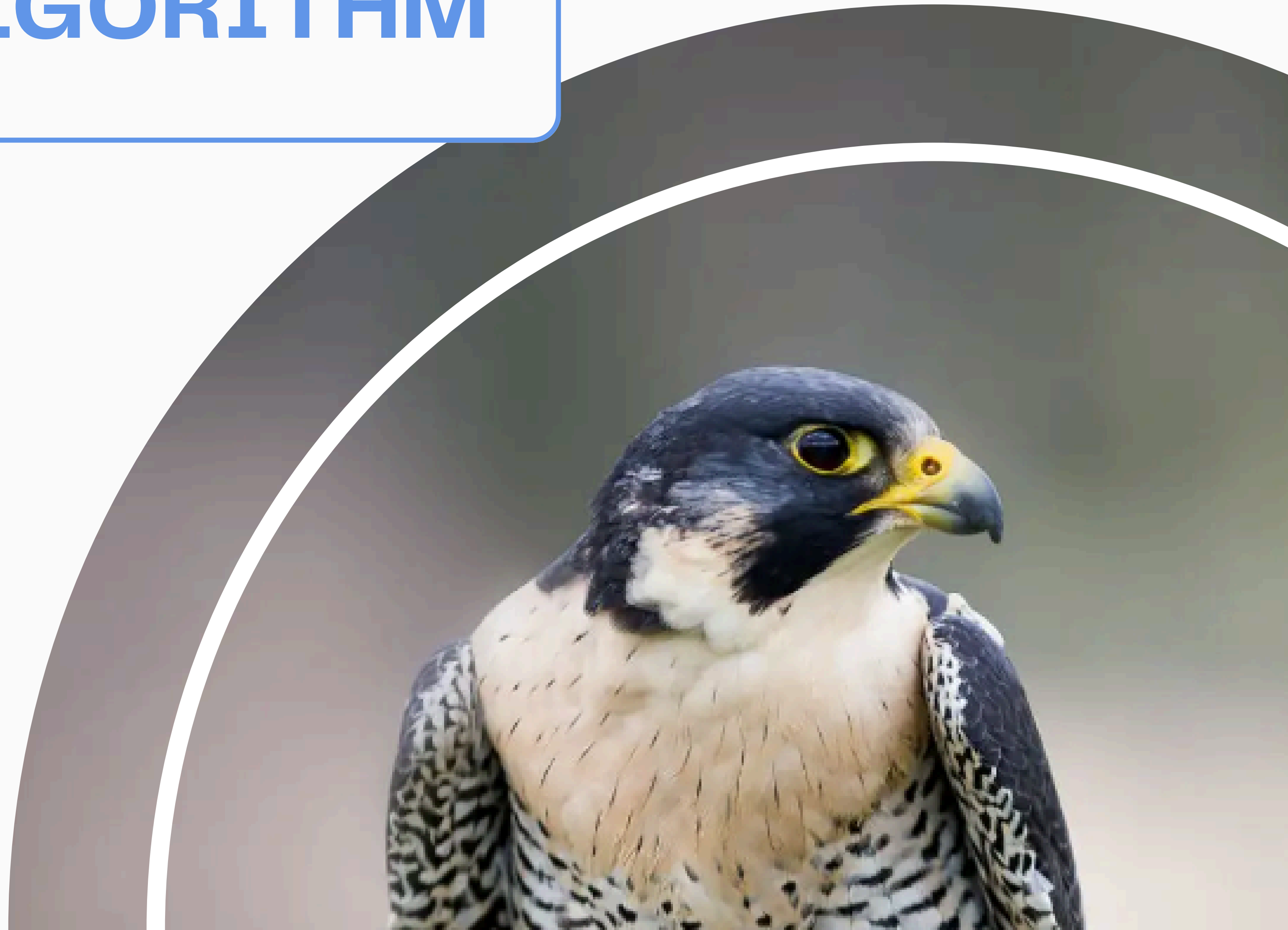
During flight, falcons take different routes to reach their prey. Each route has two parts: the first part is a logarithmic spiral on which a falcon continually keeps its head straight while peering at the prey with the highest visible acuity; and the second is when the falcon flies toward the prey in a straight segment – when the prey is within the falcon's field of vision, the falcon dives.

Therefore, a falcon's achieve locomotion can be classified into three steps: the initial step (first stage) – exploring for prey; the second step (second stage) – improving its dive through a logarithmic spiral; and the third step (third stage) – the dive itself (which can result in success; i.e., acquisition of prey).

STEPS OF FALCON OPTIMIZATION ALGORITHM

Exploration for prey	Approach	Diving and capture	Learning and adaptation	Iterative refinement	Termination
Falcons begin by exploring their environment in search of prey. In FOA, this phase involves generating random solutions or positions in the solution space. This randomness helps in covering a wide range of potential solutions.	Once a potential prey (optimal solution) is detected or inferred, falcons use a logarithmic spiral to approach it efficiently. In FOA, this phase typically involves focusing on areas or solutions that show promise, often guided by heuristic or exploitation strategies.	Upon nearing the prey, falcons execute a swift dive to capture it. In FOA, this phase corresponds to refining the search in the vicinity of promising solutions, aiming for convergence to the optimal or near-optimal solution.	hroughout the process, falcons learn from their experiences and adapt their hunting strategies based on the feedback received. In FOA, this translates to iterative refinement of solutions based on the evaluation of fitness or objective function values.	FOA iteratively refines the solutions over multiple cycles or iterations, continuously adjusting exploration, exploitation, and agility parameters to improve the quality of solutions.	The algorithm terminates based on predefined criteria (e.g., maximum number of iterations reached, convergence criteria met). The best solution found during the process is typically selected as the final output.

2 TSP BASED ON FALCON OPTIMIZATION ALGORITHM



TSP BASED ON FAO

Overview

FOA provides a novel and effective approach to solving optimization problems like TSP, offering robustness in handling complex solution spaces and potentially outperforming traditional optimization methods in certain scenarios.

In the context of TSP, FOA begins with an exploration phase where falcons, represented as potential solutions (permutations of city sequences), explore different routes through random movements akin to Levy flights. This phase allows for the exploration of diverse solutions, covering a wide search space to discover potentially optimal routes.

Once initial exploration is conducted, FOA transitions into the exploitation phase. Here, falcons adjust their movements towards more promising solutions. In the TSP context, this phase involves evaluating neighboring solutions and selecting routes that reduce the total travel distance, simulating the falcons' efficient approach towards prey using strategies like logarithmic spirals in nature.

The agility phase in FOA corresponds to fine-tuning and adjusting the search parameters to balance between exploration and exploitation. In TSP, this involves dynamically adjusting step sizes and exploration probabilities to further refine the discovered routes. This phase ensures that the algorithm does not get stuck in local optima but continues to explore potentially better solutions.

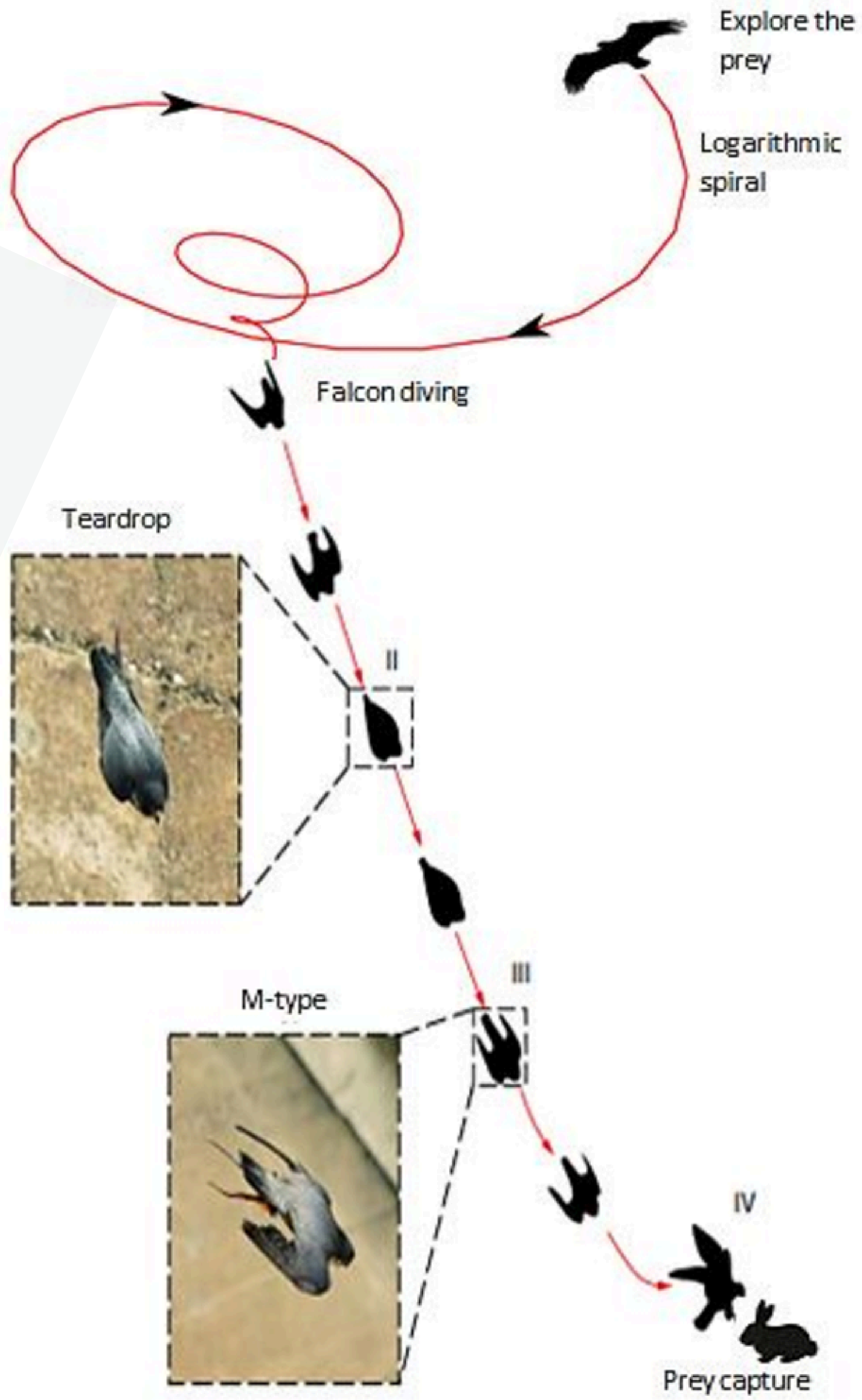
ALGORITHM STEPS

INPUTS

- **City Locations:** A list of coordinates representing the cities.
- **Number of Falcons:** The number of candidate solutions (falcons).
- **Alpha:** The Levy flight parameter for exploration.
- **Beta:** The exploitation parameter.
- **Delta:** The agility parameter (step size reduction).
- **Probability of Exploitation (p_a):** The probability that a falcon will move towards a neighboring solution.
- **Probability of Agility (p_d):** The probability that a falcon will perform random exploration with a reduced step size.
- **Maximum Iterations:** The number of iterations to perform.

OUTPUTS

- **Best Solution:** The optimal route found by the algorithm.
- **Best Distance:** The total distance of the optimal route.



- **Initialize Parameters**

  Set the parameters for FOA: number of falcons, alpha, beta, delta, p_a, p_d, and maximum iterations.
- **Generate Initial Population**

  Create an initial population of falcons where each falcon represents a random permutation of cities.
- **Calculate Fitness**

  For each falcon (candidate solution), calculate the total distance of the route (fitness).

$$\text{Fitness}(\pi) = \sum_{i=1}^{n-1} d(\textbf{city}_{\pi_i}, \textbf{city}_{\pi_{i+1}}) + d(\textbf{city}_{\pi_n}, \textbf{city}_{\pi_1})$$

$$d(\textbf{city1}, \textbf{city2}) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

- **Initialize Parameters**

  Set the parameters for FOA: number of falcons, alpha, beta, delta, p_a, p_d, and maximum iterations.
- **Main Optimization Loop:**

  For each iteration
  - **Update Falcon Positions:**

    For each falcon, update its position based on exploration, exploitation, and agility mechanisms.

    Exploration (Levy Flight) Move the falcon by a Levy flight step:

$$\text{new\_position}_i = (\text{current\_position}_i + \text{Levy\_step}) \mod n$$

Exploitation: move the falcon towards the best neighboring solution.

$$\text{Levy\_step} = \beta \cdot (\text{best\_neighbor}_i - \text{current\_position}_i)$$

Agility: perform a random exploration with a reduced step size.

$$\text{Levy\_step} \cdot \delta$$

- **Calculate Fitness for Updated Population**

  Recalculate the fitness values for the updated falcon positions.

- **Update Best Solution**

  Compare the fitness of the updated falcon positions with the current best solution.
  If a better solution is found, update the best solution and best fitness.

$$\text{best\_neighbor}_i = \arg\min_j \left\{ d(\mathbf{city}_{\pi_i}, \mathbf{city}_{\pi_j}) \mid j \neq i \right\}$$

- **Print Results**

  After completing all iterations, print the best solution and its corresponding distance.

RESULTS

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Final Best Solution: [20, 119, 95, 163, 119, 71, 214, 18, 39, 36, 140, 10, 264, 225, 241, 106, 259, 106, 41, 126, 70, 111, 111, 56, 18, 110, 24
8, 10, 224, 80, 215, 202, 7, 118, 255, 67, 249, 213, 152, 192, 233, 30, 119, 31, 112, 241, 3, 230, 198, 57, 109, 222, 15, 237, 124, 197, 135, 2
63, 184, 61, 160, 176, 138, 225, 152, 276, 167, 200, 208, 73, 34, 202, 273, 101, 91, 44, 91, 135, 62, 13, 191, 52, 266, 64, 129, 72, 17, 191, 1
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, 82, 240, 138, 201, 3, 44, 136, 250, 33, 191, 109, 165, 170, 244, 232, 77, 266, 170, 191, 69, 260, 19, 277, 171, 93, 229, 160, 175, 271, 279,
264, 194, 179, 40, 271, 96, 25, 151, 18, 50, 55, 201, 110, 136, 258, 16, 29, 120, 218, 129, 63, 255, 177, 233, 263, 2, 80, 271, 218, 240, 207,
268, 185, 233, 40, 220, 82, 37, 19, 230, 89, 142, 266, 151, 193, 109, 261, 34, 135, 263, 120, 67, 35, 6, 4, 275, 0, 106, 272, 105, 188, 187, 93
, 221, 173, 52, 127, 96, 63]
Final Best Distance: 30545.544979987968
```

Interpretation

- **Convergence:** The fitness values show improvement, indicating the algorithm's success in finding shorter routes over iterations.
- **Optimization:** The final best distance indicates the quality of the solution found. In the context of TSP, this distance represents the length of the shortest route discovered by the FOA.
- **Algorithm Performance:** The updated positions of the falcons and their corresponding fitness values indicate the efficiency of the exploration and exploitation strategies used by the FOA.

LIMITATIONS

The Falcon Optimization Algorithm (FOA), while effective in finding solutions for the Traveling Salesman Problem (TSP), does have several limitations.

- One significant limitation is its tendency to get trapped in local optima, especially when dealing with complex and highly multimodal landscapes. This occurs because the algorithm’s exploration and exploitation phases might not be sufficiently balanced, leading to premature convergence.

- Additionally, the algorithm's performance is sensitive to the tuning of its parameters (alpha, beta, delta, p_a, and p_d), and finding the optimal set of parameters can be challenging and time-consuming.

- Furthermore, the computational cost can become prohibitive as the problem size increases, as each iteration requires calculating the distances and updating the positions of all falcons, making it less suitable for very large datasets.

CONCLUSION

The application of the Falcon Optimization Algorithm (FOA) to the Traveling Salesman Problem (TSP) demonstrates its potential in solving complex optimization problems through innovative exploration and exploitation strategies. Despite its effectiveness, the FOA faces limitations, particularly in terms of susceptibility to local optima and the need for precise parameter tuning.

Merci pour votre attention