Sandpiper Food Search Algorithm: A New Optimization Approach for Agents with Limited Knowledge

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Abstract

Optimization problems have become increasingly complex, stretching the limits of conventional methods such as convex optimization, Newton-Raphson method, and others. To address this challenge, numerous metaheuristic algorithms, often inspired by nature, have emerged due to their adaptability and robustness (for example, Gray Wolf Algorithm and Ant Colony Optimization). However, functions that are non-symmetrical or have unique profiles such as basins, valleys, or plates remain challenging for these algorithms. Moreover, most of these existing algorithms have global knowledge, which is unrealistic for some real-world problems such as underground mining and spacecraft trajectory. To bridge this gap, a new biologically inspired optimization algorithm named Sandpiper Food Search Algorithm (SFSA) is proposed in this research. This algorithm is inspired by the food search behavior of sandpipers at the beach where each agent (sandpiper) explores the problem space to find the optimal area by exploiting the local search for candidate solutions around them. Moreover, this algorithm includes the wave action that forces these birds to shift from their current best position and how they would find their way back to their best position if their shift does not give a better solution. The waves' occurrence will be based on a Poisson distribution with size of 60% of the search space. The performance of the algorithm is evaluated using the Holder Table benchmark function [1]. This research provides a conceptual design of the new Sandpiper Food Search Algorithm and an initial evidence of the accuracy of the algorithm.

Research Question

How can we use sandpiper food search behavior as a new inspiration for optimization algorithms, where can we apply them, and how it compares with other algorithms?

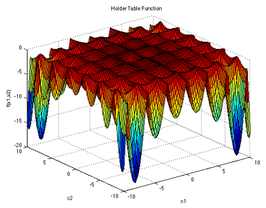
Contributions

- A New Bio-Inspired Optimization Algorithm that only requires local agent knowledge (a limitation of common approaches like Particle Swarm Optimization)
- Intitial Evidence for improved performance when incorporating Bio-Inspired wave response.

Hypothesis

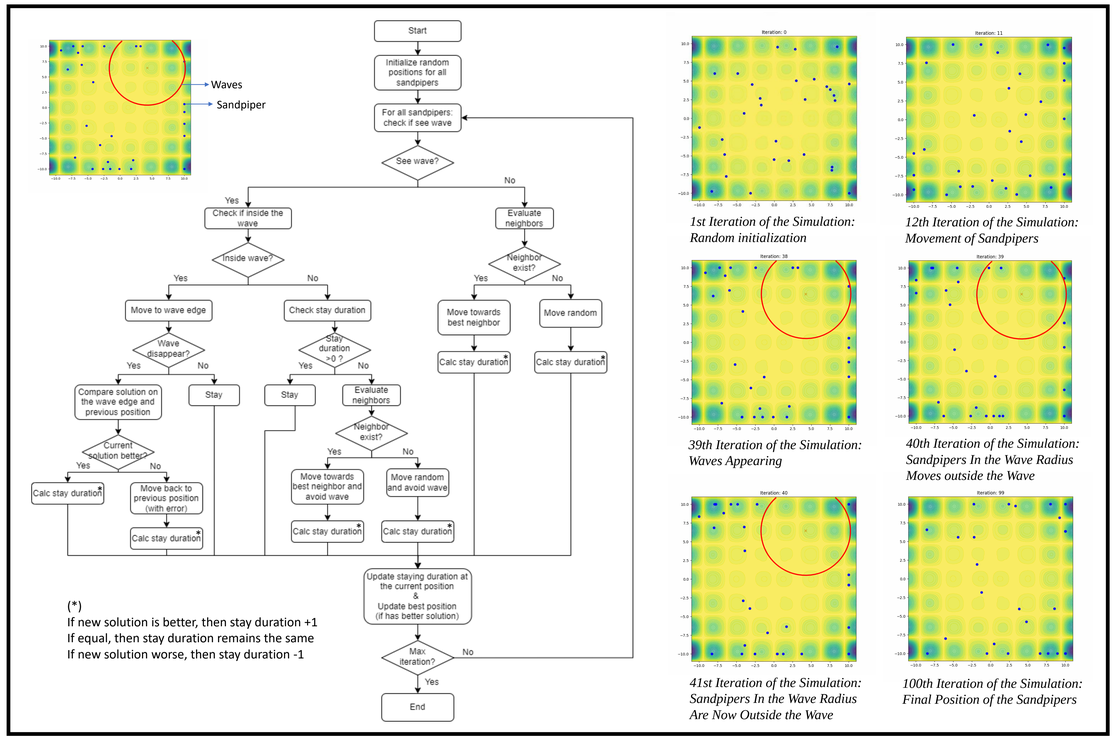
We hypothesize that sandpiper food search behavior can be a new source of inspiration for a new optimization algorithm for agents with limited knowledge.

Source: Wikipedia



Holder Table Function Plotted in 3D
Source: Surjanovic & Derek Bingham [1]

Algorithm and Simulation Overview



1st Iteration of the Simulation: Random initialization

12th Iteration of the Simulation: Movement of Sandpipers

39th Iteration of the Simulation: Waves Appearing

40th Iteration of the Simulation: Sandpipers In the Wave Radius Moves outside the Wave

41st Iteration of the Simulation: Sandpipers In the Wave Radius Are Now Outside the Wave

100th Iteration of the Simulation: Final Position of the Sandpipers

Figure 1. Sandpiper Food Search Algorithm Flowchart and Example of Simulation Overview

The algorithm is tested using the Holder Table benchmark function which has many local minima and 4 global minima with optimal solutions of -19.2065 at the [-10, 10] search space [1]. The purple region shows the optimal solution of the search space.

Results

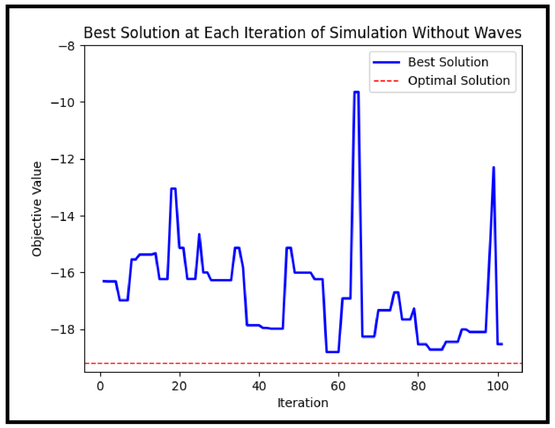


Figure 2. An Example of a Result of Simulation Without Waves

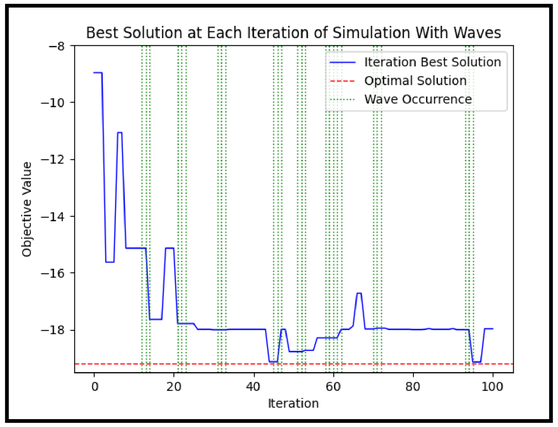


Figure 3. An Example of a Result of Simulation With Waves

Results

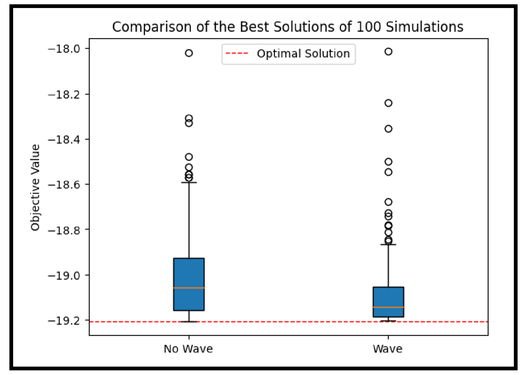


Figure 4. Comparison of the Best Solutions of 100 Simulations With and Without Waves

Figure 2 and 3 shows the best solution found at each iteration by all the sandpipers. In the example, the simulation with waves found a better solution.
This idea is proven by running 100 simulations. Figure 4 shows that simulations with waves have lower overall objective values than without waves. The median of the simulation without wave is -19.0804, while the simulation with wave is -19.1688, with a 0.46% improvement on the objective value with waves. The boxplot shows that most of the solutions of the simulation with waves are closer to the optimal solution.

Conclusion

- The Sandpiper Food Search Algorithm with waves has a better performance compared to those without waves
- Simulation results shows that this algorithm could produce a solution that is close to the optimal solution
- The Sandpiper Food Search Algorithm may be a feasible optimization algorithm that can be translatable to a real-world problem due to only requiring local agent knowledge

Future Work

- Application of the algorithm to the BID4R Roving Swarm Test Platform
- Comparison of the algorithm's performance to Particle Swarm Optimization
- ASME IDETC-CIE Conference Paper

Citations

[1] S. Surjanovic and D. Bingham, "Virtual library of simulation experiments:," Holder Table Function, https://www.sfu.ca/~ssurjano/holder.html.