Elephant Herd Algorithm for Multimodal Optimization

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Abstract

A new algorithm to deal with multimodal optimization with contending multiple solutions is presented. The algorithm is based on the social behavior of Elephants. Social traits like memory of matriarch, inter-herd and intra-herd communication, aggregation and segregation, cross-reproduction in herds are incorporated. The algorithm is tested against the standard mathematical test functions and the results are compared with particle swarm optimization and genetics algorithm.

Introduction

A wide number of **problems in engineering** don't necessarily have **explicit** or **simple mathematical equations**. Yet, they demand solution with added constraints such as time and accuracy. Optimization engineering is most often utilized to come up with acceptable solutions to these problems. The success of various nature based optimization algorithms have led to more in depth research on **behaviors of various species** around us and their formulation to solve engineering problems.

Objective

One of the **deficiencies** in optimization is the difficulty in solving **multimodal functions**. The objective is to develop new **metaheuristic optimization technique** (inspired from nature) to find out **multiple contending solutions** of problem **simultaneously**.

Multimodal optimization

Multimodal unconstrained optimization problem is defined as:

$$\min_{\mathbf{x}\in\mathbf{S}} f(\mathbf{x})$$

$\mathbf{x}_i^*$ for $i \in \{1, 2, .., n\}$ are optimal solutions of above problem.

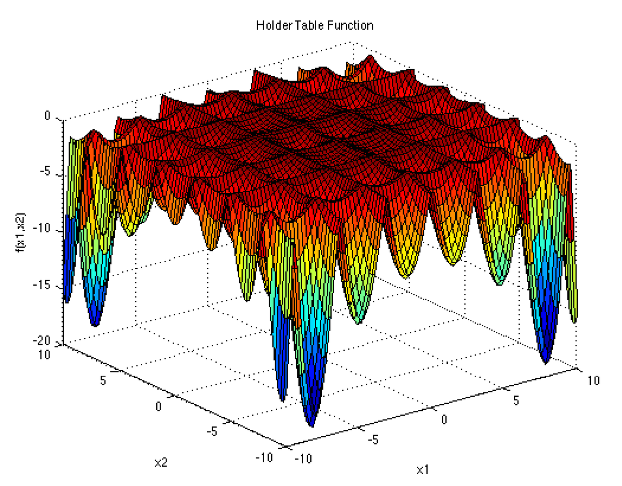

Figure 1: Holder table function (2 variables) with 4 global minima in the interval $[-10, 10]^2$

Behavior of Elephants

1. **Social structure**
   - (a) Elephants live in **herds** (female and children), which is the basic unit of their social structure [5].
   - (b) Every herd has a **dominant mother elephant**, who acts as the memory of the herd called Matriarch [3].
2. **Communication**
   - (a) **Intra-herd Communication**: Updation of knowledge about the environment like locations of food, water, etc. is done by the members of the herd to their respective Matriarch.
     - i. **Scout Communication**: The bull elephant, while wandering, communicates with the matriarch of herd, which, sometimes may lead the herd to better food [2].
     - ii. **Members Communication**: There are other elephants in the herd (calves, younger females, juvenile elephants) who roam around the place when a herd is on the move. They too update the Matriarch with new information [5].
   - (b) **Inter-herd Communication**: This communication is the interaction between the Matriarchs of two herds exchanging the information about their positions with the help of infrasonic sound waves [4].
3. **Movement**
   - (a) **Scout (Bull) Movement**: The bull elephants do not remain with the herd and wander around though they keep on communicating with the Matriarch.
   - (b) **Member Movement**: Movement of members of the herd is defined by Matriarch. Members move in coordination with the herd.
4. **Herd dynamics**
   - (a) **Aggregation**: Different herds interact with each other and might congregate to form a single herd with one matriarch in case one of them has scarce food [6].
   - (b) **Segregation**: Younger matriarchs usually have **mediocre memory**, hence, the herd size decreases due to segregation [6].
   - (c) **Reproduction**: The elephant species breeds throughout the year with no distinct seasonal acceleration. Females have **selective criteria** for choosing their mates [1].

Implementation

1. **Social Structure**: Create herd as **structure** with **scouts**, **members** and **memory-stack** to be the elements. **Scouts** and **Members** stores the **position** and **velocity** of elephants, while **memory-stack** keeps track of **best** and **worst solution**.
2. **Communication**: The **Scouts** of each herd **communicate with Matriarch** of the herd after **certain interval** (Memory-stack gets updated). Members communicate with matriarch after every iteration and updates their positions to her.
3. **Aggregation**: The herd **collaborate their search** by aggregating and forming a **single herd with leader** being the **oldest matriarch** (best memory-stack) among them.
4. **Segregation**: The herd whose **best memory** value is **least** among all the herds, would **fragment into two herds** with same memory information.
5. **Reproduction**: A **best scout** from one herd is chosen and then reproduce with matriarch of another herd, i.e, **crossover** between **scout** and **matriarch**(memory-stack) takes place producing two new children. If children values are better, the memory-stack is updated.

The velocity and position update of scout and member is as follows:

$$v_{s_i}^{j+1} = v_{s_i}^{j} + \alpha rand\frac{(x_u - x_l)}{6} \qquad v_{m_i}^{j+1} = v_{m_i}^{j} + w_1(memstack^j - x_{m_i}^j) + w_3 rand(x_u - x_l)$$

$$x_{s_i}^{j+1} = x_{s_i}^{j} + v_{s_i}^{j+1} \qquad x_{m_i}^{j+1} = x_{m_i}^{j} + v_{m_i}^{j+1}$$

Algorithm 1 Elephant Herd Algorithm

```
Define Objective function f(x) where x = (x_1, x_2, ..., x_d)^T
Create elephant population (N herds with each of S scouts and M members)
for i = 1 to iter_max do
  if i == 1 then
    for j = 1 to N do
      randomly generate positions and velocity of elephants in herd j
      evaluate objective function f(x) for each elephant in the herd j
      Compute the local best from the members' values and update memory-stack of herd j
    end for
  else if i == multiple(t_1) then
    do scout communication
  else if i == multiple(t_2) then
    do reproduction
  else if i == multiple(t_3) then
    do global communication
  else if i == multiple(t_4) then
    do aggregation
  else if i == multiple(t_5) then
    do segregation
  end if
  for j = 1 to N do
    compute memory-stack of herd j
    compute velocity and positions of member & scout elephants of herd j
    evaluate objective functions of member and scout elephants of herd j
  end for
end for
compute global best from all herds
```

Results

The elephant herd algorithm is tested on different benchmark functions and compared with multiple colony particle swarm optimization (MC-PSO) and Niching genetics algorithm. the results are tabulated below.

Function	Global minima (#)	EHA	MC-PSO	Genetics Algorithm
Ackeley's	0(1)	0(1)(6580)	0(1)(4502)	0(1)(8032)
Holder table	-19.2085(4)	-19.2085(1)(21230)	-19.2081(0.78)(25134)	-19.2085(0.95)(38943)
Egg-holder	-959.6407(1)	-959.6406(1)(19982)	-959.640(0.88)(24234)	-959.6406(0.93)(28943)
Griewank	0(1)	0(0.95)(24143)	0.23(0.34)(28756)	0(0.86)(39654)
Shubert	-183.7309(Several)	-183.7308(10)(37654)	-183.7302(3)(28654)	-183.7306(7)(45434)
Cross-in-Tray	-2.06261(4)	-2.06259(1)(23435)	-2.06254(0.62)(27654)	-2.06261(0.95)(32870)

Table 1: Comparison Table of Elephant Herd Algorithm(EHA) with Multiple Colony Particle Swarm Optimization(MC-PSO) and Genetics Algorithm (GA) on standard test functions. Results format: Global minima(Success Ratio)(Number of functions evaluations)

The positions of elephants on simulation for finding minima of holder table function has been shown below.

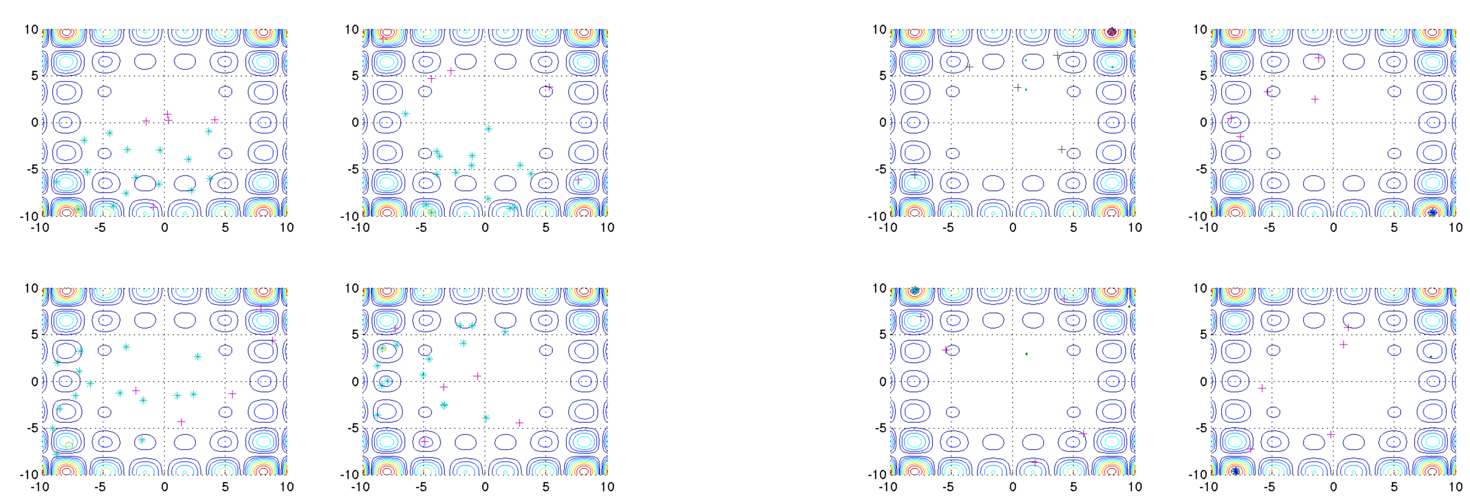

Figure 2: Elephant Herd Algorithm simulation on Holder table function (4 herds with each 15 members and 5 scouts) left - 10 iterations, right - 1000 iterations

Conclusions

- Simulations and comparison show that Elephant Herd Algorithm is superior to these existing algorithms for functions with multiple contending solutions in terms of success ratio and NFE.
- The global exploration with local exploitation as well as aggregation and segregation guiding herd population to find multiple solutions simultaneously.

References

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