Use Two Kind Hybridization of the Chaotic Peafowl Algorithm with the Hummingbird Algorithm

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ABSTRACT

The wide spread of living organisms in nature and how they obtain food has prompted many scientists to form mathematical models that simulate these organisms. These models were used to solve math problems that take a long time and effort to solve, but these models were sometimes weak and required modification. In this research we used two methods to reach the optimal solution, the first method we used the Peafowl optimization algorithm (POA) with the chaos function and the chaotic tent function to reach the optimal solution and this was the first step in the work, the second method we hybridized the first step by adding the artificial hummingbird algorithm (AHA) The hybridization was of two types, the first by linking communities and the second by linking equations, and we got the optimal solution using 1000 iterations in the two steps, which resulted in producing the optimal solution.

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1. Introduction

proposed intelligent algorithms that mimic the flight and foraging behavior of organisms in nature. This simulation takes place with three types of foraging stages, which are pivotal, diagonal, and multidirectional.

Meta-Heuristic Algorithm (MHA) [1], [2] Inspired by the observation of animal species that live in flocks or live in an isolated way in nature [3-5], where researchers monitor some of these species and study their behavior in search of food [6]. Scientists created mathematical models in the form of algorithms to simulate these animals, which were then used to solve mathematical problems and improve methods of solving them to reach the best solutions.

The Peafowl Improvement Algorithm (POA) caught the attention of researchers by observing the habits and behavior of Peafowl (POA) in nature. Where males are distinguished by their long tail compared to females with short or no tail, and their behavior is divided into two parts: social behavior and spatial behavior. [7-10].
Hummingbirds are incredible creatures and are the smallest birds on the planet. If intelligence is assessed by comparing their brain-to-body ratio, there are more than 360 species of hummingbirds worldwide. [11-14].

Chaos map has been used in many fields for the purpose of scientific research, as it has been used in several scientific fields, including mathematics, engineering, physics, biology and other sciences. Where chaos is divided into two parts: deterministic and non-deterministic chaotic systems. The first description of a chaotic process was given in 1963 by Lorenz [15] who developed a system called the Lorenz attractor, along with nonlinear differential equations [16-19].

In this paper we used the chaos method with the Peafowl algorithm (POA) as a first step, then we hybridized it with two types of hybridization, the first through the community and the second through equations, using the artificial hummingbird algorithm (AHA), which represents the second step to obtain the results that represent the solution optimum.

2. Artificial Hummingbird Algorithm (AHA)

Hummingbirds are incredible creatures and they are the smallest birds on the planet. There are more than 360 species of hummingbirds around the world. Like the bee hummingbird, it is the smallest of the hummingbirds, measuring 5.4 cm in length and 1.84 g in weight on average. This bird eats a lot of flower nectar [20] - [23].

The three core components of an algorithm (AHA):

Food: Hummingbirds look for food in the wild based on the qualities of the food. They favor nectar from flowers. The characteristics of these sources are taken into consideration by the bird in terms of the quantity and frequency of nectar replenishment. The value of functional fitness, the higher the fitness rating, the quicker the nectar replaces the food supply.

Hummingbird: A particular food source is designated for each hummingbird. Bird could consider the location and rate of nectar replenishment for a certain food source and share that knowledge with the rest of the group. The amount of time that has passed since a hummingbird last visited a particular food source is another thing, they may keep track of.
The AHA algorithm's pseudo code is shown in Figure.

```
START

Initialization

While

The stop requirement is not satisfied

Foraging with a guide

Foraging on a territorial scale

Foraging during migration

END
```

2.1. Algorithm and mathematical model

The hummingbird algorithm is expressed mathematically, as shown below:

\[ m_i = L + p \cdot (U - L) \quad i = 1, \ldots, k \tag{1} \]

where \((L)\) and \((U)\) are the upper and lower limits for a \(d\)-dimensional problem, \(p\) is a random vector in \([0, 1]\), and \(m_i\) is the location of the \(i\)th food source that provides the answer to a given problem. The visit table of food sources was first initialized as follows:

\[ VT_{ij} = \begin{cases} 0 & \text{if } i \neq j \\ \text{null} & \text{if } i = j \end{cases} \quad i = 1, \ldots, k; j = 1 \ldots, k \tag{2} \]
where for \( i = j \) \( VT_{i,j} = \text{null} \) implies that each hummingbird is consuming food from its own source; for \( i \neq j \), \( VT_{i,j} = 0 \) indicates that the \( i \)th hummingbird in the current iteration has just visited the \( j \)th food source.

### 2.2. Food with a guide

The target food should have a high rate of nectar replenishment and a long period of visits for that hummingbird since each hummingbird instinctively seeks the food source with the highest volume of nectar. This hummingbird may fly to its preferred food source once it has found it. The AHA approach successfully enhances and defines three flight capabilities: omnidirectional, radial and pivot flights. This is done by providing a vector that switches direction while foraging. This vector defines which directions can be reached in two-dimensional space. Diagonal flight, on the other hand, enables the hummingbird to fly between any two of the three coordinate axes, hummingbirds may move along any coordinate axis. Any direction of flight can be projected onto any of the three coordinate axes. Thanks to multi-directional flight, only hummingbirds have the ability to fly axially and diagonally, although all birds are capable of flying in all directions. To expand on these flight patterns, use the following axial flight definition.

#### d-D space:

\[
H^i = \begin{cases} 
1 & \text{if } i = \text{rand}([1,h]) \\
0 & \text{else} 
\end{cases} \quad i = 1, \ldots, h
\]  

The following are the details of a diagonal flight:

\[
H^i = \begin{cases} 
1 & \text{if } i = 0(j), j \in [1, H], 0 = \text{randperm}(d), d \in [2, r1.(H - 2)] + 1 \\
0 & \text{else} 
\end{cases}
\]

Flying in an omnidirectional manner is defined as:

\[
H^i = 1 \quad i = 1, \ldots, h
\]

where \( \text{randperm}(d) \) produces a random integer permutation between the numbers 1 and \( h \), where \( r1 \) is a random number in \((0, 1]\), and \( \text{Rand}([1, h]) \) produces a random integer between 1 and \( d \). Any coordinate axis from 2 to \( d - 1 \) can be used to define a hyperbolic rectangle. This demonstrates that mathematical models of flying abilities may imitate hummingbird search behaviors in three-dimensional and multi-dimensional settings. The humming (AHA) visits the target food source, resulting in the receipt of a supply of filter food. As a result, the food source is updated in relation to the target food source selected from the previous source, all of the available sources. The mathematical formula for simulating directed foraging behavior and a prospective food source is given below:

\[
v_n(l + 1) = x_{n,tbr}(l) + b.D.(x_n(l) - x_{n,tbr}(l)) \quad \text{(6.)}
\]

\[
b \sim B(0,1)
\]

where \( x_n(l) \) shows where the \( i \)th food supply is at any given time. \( t \), \( x_{n,tbr}(l) \) represents the position of the targeted target food source for the \( i \)th hummingbird, and \( b \) denotes a directed factor that fits the normal distribution. A variety of flying patterns with a mean of \( 0 \) and a standard deviation of \( 1 \) are used by hummingbirds to participate in directed foraging, as stated by \( b \sim (0,1) \) Eq. (6.) It enables each existing food source to change where it is in relation to the desired food source. The most recent location information for the \( i \)th food source is as follows:

\[
x_n(l + 1) = \begin{cases} 
x_n(l) & f(x_n(l)) \leq f(v_n(l + 1)) \\
v_n(l + 1) & f(x_n(l)) > f(v_n(l + 1)) 
\end{cases}
\]

where the function’s fitness value is indicated by \( f(.) \). If the candidate food source’s rate of nectar replenishment is greater than the existing one, according to Eq. (8), the hummingbird will leave its current feeding location and feed at the candidate food source (6).

### 3. Peafowl optimization algorithm (POA)
parts of China, unlike the blue Peafowl, which is widely distributed in Southeast Asia. Male Peafowl are famous for their long tails and luxurious plumage, unlike females, which have short or no tails. The Asian species engage in courtship rituals that involve the use of a "tail" or "row" of concealed feathers. Depending on their activity, males roam around females and flaunt their beautiful plumage to show their dominance and entice females to mate. If a male is more attractive than other males, more females may flock to him. Peafowl can be classified into groups that breed, search for food, be social, and move in space. Foraging is one of the most important aspects of bird behavior and one of the most important actions of birds. It also gives us a solid basis for investigating how environmental factors influence flocks. Peafowl open their plumage when they locate a food source and spin dance routines to extend their range and attract females. There are two alternating dance positions: circling around the site and around the food source. Figure (3) of the Peafowl [24] - [27].

![Peafowl](image.png)

*Figure 3. The Peafowl.*
This section presents mathematical models of several cognitive processes of Peafowl. Then the basic operations of the POA are explained. To create an appropriate mathematical model for the various individual behaviors of a Peafowl flock, such as courtship, foraging, and chasing, the Peafowl community is divided into three roles: adult Peafowl, young Peafowl, and Peafowl juvenile. Each Peafowl is evaluated according to how valuable its behavior is. Peafowl 1, Peafowl 2, Peafowl 3, Peafowl 4 and Peafowl 5 which are identified as Mature Peafowl are the top five answers to the optimization challenges. The first 30% of individuals are classified as adult Peafowl, leaving the remaining 70% as juvenile. Both adult and juvenile peafowl display distinct behaviors that are strongly influenced by adult peafowl.

In order to ensure compliance (POA), it is also necessary to redistribute tasks among individuals depending on their fitness values after each iteration. This is because, unlike natural populations, the role of each individual in the peafowl flock may change over time, peafowl engage in courtship behaviors such as circling around a food source to show off in an attempt to attract females and increase the likelihood of mating. Males adopt an exquisite dance posture when approaching females, spreading their tails which is a sign of courtship. Some estranged courtship behaviors, including flapping, flapping of feathers, and tail extension, have three main phases. They cycle from 0 to 15 circles around the female, rising and spreading their tail feathers like fans, the male wagging the tail intermittently, quickly, and at a high frequency to produce a swishing sound that attracts the female's attention during the tail-showing phase. The proposed technique focuses on turning behaviors that may actually lead to changes in fitness value over the course of repetition in order to describe the activities of peafowl using mathematical language and an accurate and cost-effective mathematical model. It is important to keep in mind that the rotational behaviors of male peafowl may involve either circling on site or circling around a food source after extending their tails. The only criterion used to choose between the two spinning behaviors is their fitness values.

peafowl with higher levels of fitness are more likely to circle the food source in a wider circle, while peafowl with lower levels of fitness are more likely to circle the food source in a smaller circle radius. But the following can be done to develop such a mathematical model:

\[
x_{uc1} = x_{uc1}(t) + 1 \cdot R_s \cdot \frac{x_{o1}}{\|x_{o1}\|} \quad (9)
\]

\[
x_{uc2} = \begin{cases} x_{uc2}(t) + 1.5 \cdot R_s \cdot \frac{x_{o2}}{\|x_{o2}\|}, r_1 < 0.9 \\ x_{uc2}(t), \text{ otherwise} \end{cases} \quad (10)
\]

\[
x_{uc3} = \begin{cases} x_{uc3}(t) + 2 \cdot R_s \cdot \frac{x_{o3}}{\|x_{o3}\|}, r_2 < 0.8 \\ x_{uc3}(t), \text{ otherwise} \end{cases} \quad (11)
\]

\[
x_{uc4} = \begin{cases} x_{uc4}(t) + 3 \cdot R_s \cdot \frac{x_{o3}}{\|x_{o3}\|}, r_3 < 0.6 \\ x_{uc4}(t), \text{ otherwise} \end{cases} \quad (12)
\]

\[
x_{uc5} = \begin{cases} x_{uc5}(t) + 5 \cdot R_s \cdot \frac{x_{o5}}{\|x_{o5}\|}, r_4 < 0.3 \\ x_{uc5}(t), \text{ otherwise} \end{cases} \quad (13)
\]

\[x_o = 2 \cdot \text{rand} (1, \text{Dim}) - 1 \quad (14)\]

where \(x_{uci}\) represents the location vector of the male peafowl \(i = 1, 2, \ldots, 5\); \(R_s\) represents the radius of rotation; \(X_o\) represents a random vector; \(X_o\) refers to modules of \(X_o; o_1, o_2, o_3, o_4\) a set of four random integers with a consistent distribution \((0, 1)\); Dim denotes the number of variables. Furthermore, it, rotation \(R_s\) with each cycle, the radius is supposed to alter dynamically. It can be explained as:

\[R_s(t) = R_{so} - (R_{so} - 0) \left(\frac{t}{t_{\text{max}}}\right)^{0.01} \quad (14)\]
where $t$ and $t_{\text{max}}$ reflect the number of iterations that have already occurred and the maximum number of iterations; $R_{\text{so}}$ represents a starting radius. Using the search space of the optimal problem, the rotation radius vector may be calculated as follows:

$$R_{\text{so}} = C_v(X_U - X_L) \quad (15)$$

Where $X_U$ and $X_L$ signify the searching space's upper and lower limits; $C_v$ is possible to establish the visibility factor of peafowls circling at 0.2.

4. Chaotic Map

The chaotic map is a mathematical model that has been applied and used in many intelligence algorithms in order to improve them and get the best solutions. Chaos is associated with dynamic systems that are sensitive to starting conditions, because every change in them has an effect on the final outcome. Chaotic systems show unpredictable behavior, and random maps create chaotic sequences. This section contains a variety of chaotic maps. It will be used to improve the performance of the algorithm [28] - [30].

4.1. Tent Chaotic Map

The chaos map has many types, including the tent, which is described mathematically as follows: [31] - [33].

$$x_{n+1} = \begin{cases} 2x_n & x_n < \frac{1}{2} \\ 2(1 - x_n) & x_n \geq \frac{1}{2} \end{cases} \quad (16)$$

Where $x_n$, Tent map produces chaotic sequences in the range of 0 to 1.

4.2. Gauss Map

Another well-known and frequently used map for producing chaotic sequences is the Gauss map[34]–[36]:

$$x_{n+1} = \begin{cases} 0 & x_n = 0 \\ \frac{1}{x_n \mod (1)} & \text{otherwise} \end{cases} \quad (17)$$

5. Working Idea

The work is divided into two main stages: the first use of the chaotic map with the Peacock algorithm, which approaches the optimal solution, and the second stage is the hybridization of the first stage by adding the artificial hummingbird AHA. It is based on the creation of a two-part hybrid. The first hybridization is by linking communities, where the basis of its work is to take the best community from the first algorithm and place it as an initial community for the second algorithm, and the second hybridization is by linking the equations by taking the speed equation for the first algorithm and linking it to the equations of the second algorithm in order to improve them and obtain results that represent the optimal solution. Compare the results with the original algorithms and the first step. As shown in Table 1, 2, and 3, which represents using a Gauss Chaotic map with POA and then cross-hybridizing it [37] - [40]:

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
<th>D</th>
<th>Range</th>
</tr>
</thead>
</table>
| Table 1 - represents the minimum value functions:
\[ f_1(x) = \sum_{i=1}^{n} x_i^2 \]

\[ f_2(x) = \sum_{i=1}^{n} |x_i| + \prod_{i=1}^{n} |x_i| \]

\[ f_3(x) = \sum_{i=1}^{n} \left( \sum_{j=1}^{n} x_j \right)^2 \]

\[ f_4(x) = -\sum_{i=1}^{n} (x_i \sin(\sqrt{|x_i|})) \]

\[ f_5(x) = \sum_{i=1}^{n} (|x_i + 0.5|)^2 \]

\[ f_6(x) = \sum_{i=1}^{n} ix_i^4 + \text{random}[0,1] \]

\[ f_7(x) = -\sum_{i=1}^{n} [x_i^2 - 10 \cos(2\pi x_i) + 10] \]

\[ f_8(x) = -20\exp(-0.2\sqrt{\frac{1}{n} \sum_{i=1}^{n} x_i^2}) \]

\[ f_9(x) = \frac{1}{4000} \sum_{i=1}^{n} (x_i - 100)^2 - \prod_{i=1}^{n} \cos\left(\frac{x_i - 100}{\sqrt{i}}\right) + 1 \]

\[ f_{10}(x) = \frac{\pi}{2} \{10\sin^2(\pi x_1)
+ \sum_{i=1}^{n-1} (y_i - 1)^2 \times [1 + 10\sin^2(\pi y_i + 1)]
+ (y_n - 1)^2 \} + \sum_{i=1}^{30} u(x_i, 10, 100, 4) \]

Table 2 - the use of the Tent Chaotic Map with POA and then its crossbreeding.

<table>
<thead>
<tr>
<th>No.</th>
<th>Function</th>
<th>POA</th>
<th>TPOA</th>
<th>TPOA_AHA1</th>
<th>TPOA_AHA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>sphere</td>
<td>3.6721 e-07</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F2</td>
<td>Schwefel 2.22</td>
<td>3.3368 e-07</td>
<td>1.2251 e-122</td>
<td>1.2603e-272</td>
<td>0</td>
</tr>
<tr>
<td>F3</td>
<td>Schwefel 1.2</td>
<td>2.1389 e-07</td>
<td>3.113e-175</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F4</td>
<td>Schwefel 2.21</td>
<td>0.0088</td>
<td>5.198e-107</td>
<td>3.2641e-260</td>
<td>0</td>
</tr>
<tr>
<td>F5</td>
<td>Step</td>
<td>3.5318e-07</td>
<td>0.0034</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F6</td>
<td>Quartic</td>
<td>0.0076</td>
<td>1.4316 e-04</td>
<td>2.9069e-05</td>
<td>0</td>
</tr>
<tr>
<td>F7</td>
<td>Rastrigin</td>
<td>1.908</td>
<td>4.4409e-15</td>
<td>8.8818e-16</td>
<td>0</td>
</tr>
<tr>
<td>F8</td>
<td>Ackley</td>
<td>0.1003</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>F9</td>
<td>Griewank</td>
<td>0.3101</td>
<td>6.7528 e-06</td>
<td>4.4861e-23</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 3 - represents the use of the Gauss Chaotic Map with POA and then its crossbreeding

<table>
<thead>
<tr>
<th>No.</th>
<th>Function</th>
<th>POA</th>
<th>GPOA</th>
<th>GPOA_AHA1</th>
<th>GPOA_AHA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Sphere</td>
<td>3.1618 e-07</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>F2</td>
<td>Schwefel 2.22</td>
<td>3.8645 e-07</td>
<td>2.3615 e-197</td>
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<td>F3</td>
<td>Schwefel 1.2</td>
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<td>3.3125e-281</td>
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</tr>
<tr>
<td>F4</td>
<td>Schwefel 2.21</td>
<td>1.2693</td>
<td>1.2605 e-199</td>
<td>2.3127e-272</td>
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<tr>
<td>F5</td>
<td>Step</td>
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<td>F6</td>
<td>Quartic</td>
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<tr>
<td>F7</td>
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<td>F8</td>
<td>Ackley</td>
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<td>1.9540 e-15</td>
<td>8.8818e-16</td>
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<tr>
<td>F9</td>
<td>Griewank</td>
<td>0.0116</td>
<td>0</td>
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<tr>
<td>F10</td>
<td>Penalized</td>
<td>0.2808</td>
<td>8.4094 e-06</td>
<td>9.4416e-06</td>
<td>0</td>
</tr>
</tbody>
</table>

6. Conclusion

This paper proposed a POA method using Chaotic Map to increase the algorithm’s performance and achieve the best result. We saw that we didn’t get the best result in several functions, so we enhanced them by utilizing a second algorithm AHA and cross-breeding it with the first. By comparing the first and second tables, we can see that the cross-over led us to the best answer.

References


2022.


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