Modified Chimp Optimization Algorithm Based On Classical Conjugate Gradient Methods

Noor Maan Abdul Jabbar ¹, Prof. Dr. Ban Ahmed Mitras ²

¹ M.sc. Student, department of mathematics, college of computer sciences & mathematics, Mosul university.
² Prof. Dr. department of mathematics, college of computer sciences & mathematics, Mosul university.

E-mail: noor.csp105@student.uomosul.edu.iq, banah.mitras@gmail.com

Abstract. In this paper, a new hybrid algorithm was proposed for the chimp algorithm using another traditional efficient algorithm called the Conjugate Gradient Algorithm called (CGA). The algorithm CG works to optimize the randomly created elementary community as the basic community of chimp optimization algorithms by using the characteristic traditional algorithm above. The test was applied to (10) high-efficiency optimization functions with different dimensions and frequency. The results of the hybrid algorithm were excellent, encouraging, and superior to the original algorithm. The hybrid algorithm achieved optimal solutions by reaching to a minimum value \( f_{min} \) for most of these functions.

Keywords. Optimization, Chimp Optimization Algorithm, Swarm Intelligence, Conjugate Gradient Methods, Meta-Heuristic Algorithms.

1. Introduction

Optimization or nonlinear programming is one of the oldest sciences, and it expands and extends into all of our daily life. The researcher and professor at Harvard University (Yogi He) described the importance of optimization by saying: “Optimization is the cornerstone of the development of civilization ” And with the existence of the human being, who will do his best to achieve perfection in many areas so he is trying to reach the ultimate happiness in his life with the least amount of effort [2 ,1]

While mathematically, it means finding the maximum or minimum value of a function with n variables \( f(x_1, x_2, ..., x_n) \). Most mathematical problems exist in many practical situations that need to find the optimal solution for the function \( f(x) \) where \( x \) is a real vector with an dimension n [3]. There are two types of algorithms for solving mathematical optimization problems they are Deterministic algorithms and consist of algorithms that use the derivative based on the basis of its operation it is called the algorithm that depends on the derivative (slope). One of those methods that depends on specific algorithms are the Simplex Method in linear programming and the Newton-Raphson algorithm that uses the values of the objective function and its derivatives. As for the other type Stochastic algorithms have
two types of algorithms, although the difference between them is small heuristic algorithms and meta-heuristic algorithms [4].

The term metaheuristic was first introduced by Glover in 1986, and in general, these algorithms do its job better than intuitive algorithms. It should be noted that this algorithm does not contain its own definition, in some cases it is called Heuristic or Metaheuristic, but in general it is considered one of the random algorithms that use random distribution and local search [5].

In (2020) a new algorithm was proposed by Khishe M, M R Mosavi, called Chimp optimization algorithm, an algorithm inspired by individual chimpanzee intelligence and sexual drive in mass stalking, which differs from other social predators [6].

In the same year, the researcher (A Saffari) and others designed a fuzzy sample for control standers and improved the algorithm for automatic identification of sonar targets, and it was compared with algorithms with a classification accuracy rate of 97.42% in sonar data and its performance was better than other standard algorithms [7].

In the same year, the researcher (Khishe M) and (M R Mosavi) with him classified the underwater audio data set using the neural network trained through the chimp improvement algorithm and the results of this algorithm were compared with the results obtained from the GWO and IMA algorithms, as the invention showed an efficiency compared to other algorithms [8].

In 2021, the researcher (M Kaur) and others proposed a new merger of sine and cosine with the algorithm for optimizing chimp for HLS for data paths in digital filters and engineering applications, called SChOA, and the results were efficient, effective and fast-approx compared to the rest of the other algorithms [9].

2. Chimp Algorithm
Chimp (or as it is also called chimpanzee) is one of the African species of great apes, and it is the most similar to humans in some of its features [10], chimp as well as dolphins have the same brain size ratio as humans (BBR) [11, 12].

Chimpanzee settlement is a division-merging community. This type of community varies over time in the settlement range, and the organs move throughout the environment. Chimp which live in settlements of division and merging, have a dynamic specialization in group formation [13]. Looking at these issues, the concept of an independent group has been proposed, and it means that each group of chimpanzees independently attempts to uncover the scope of the research with its own strategy. Chimp are not exactly the same in terms of intelligence and ability, but they do effectively perform their duties as members of the settlement. Thus, each individual's energy can be beneficial in a specific behavior [14]. Chimp settlement contains four types of them with the title Driver, Barrier, Chaser and Attacker. They all have different abilities, so these types are essential for success. A chimp driver follows the victim without catching it. The barriers place themselves in a tree to build a fence by pushing out victim. As for the chimp chaser, they are moving fast after the victim to catch up. In the final level of the chase, the attackers anticipate the direction of the victim's movement by changing its course in the direction of the Chasers or lowering it down to the bottom. Presumably, attackers need more experience and knowledge to anticipate the movement of the next victim's path, and thus are rewarded with a better piece of meat after an effective hunt. The important role played by the attacker is closely related to age, intelligence and physical ability. Moreover, groups of chimp can change their work tasks while chasing the victim or maintain their duty while hunting [15].

In general, the hunting process is divided into two basic stages: exploration that depends on leading, blocking and Pursuing the victim, and exploitation that depends mainly on attacking the victim.
Figure 1. shows two stages of the hunting process where (a) Illustrates the first stage of the hunting process (exploration) and (b) the second stage of the hunting process (exploitation), all concepts of ChOA will be mathematically formulated later.

2.1. Chimp Optimization Algorithm (ChOA)

The research process in ChOA begins with the initialization of a random group of chimp (selected solutions). Then, groups of chimpanzees are randomly divided into four separate groups designated as Attacker, Barrier, Chaser and Driver. Each chimp updates its parameters using group strategy. During the repetition phase, the attacker, the barrier, the stalker, and the chimp driver predicts the location of the candidate victims' location. Each chosen solution begins with an update of the victim's distance. The adaptive control of the parameters $m, c$ avoids the local optimum solution and velocity in the convergence curve simultaneously, after which the $f$ parameter is reduced from 2.5 to 0, to strengthen the exploitation and attack on the victim. Since the inequality $|a| > 1$ They are unequal thus it will lead to different solutions chosen, otherwise it will ultimately lead to rapprochement towards the victim [6].

2.2. Mathematical Sample [8]

In this part, the mathematical samples of independent groups are presented as well as the four types of groups of chimp which are leading, blocking, stalking, and victim attack. The corresponding ChOA algorithm is illustrated as follows:

2.2.1. Leadership And The Pursuit Of Victim

The victim is caught during the exploration and exploitation phases, as mentioned previously, and the behavior of chimpanzees will be mathematically sampled in terms of leading and pursuing the victim through equations (1) and (2) as follows: [16].

\[
d = |c \cdot x_{prey}(t) - m \cdot x_{chimp}(t)| \tag{1}
\]
\[
x_{chimp}(t + 1) = x_{prey}(t) - a \cdot d \tag{2}
\]

$t$ denotes the number of current iterations, $a, m, c$ is the vector constants, $x_{prey}$ is the victim position vector and $x_{chimp}$ is the chimp position vector. The vectors $a, m$ and $c$ are calculated by the equations. (3), (4) and (5) as follows:

\[
a = 2f \cdot r_1 - f \tag{3}
\]
\[
c = 2 \cdot r_2 \tag{4}
\]
\[
m = Chaotic\_value \tag{5}
\]
The parameter $f$ is reduced non-linearly from 2.5 to 0 through iterations (in both the exploitation and exploration phases), where $r_1$ & $r_2$ are random vectors located in the period $[0,1]$. Finally, $m$ is a chaotic vector that was computed by a different chaotic map so that this vector is the social stimulus effect of chimp in the pursuit process) [17], and to illustrate the effect of equations (1) and (2), by observing Figure 2. Where (A) shows a graph 2D plot of the chimp location vector and several predicted locations. Moreover, a chimp in the position $(x, y)$ can change its position in relation to the position of the victim $(x^*, y^*)$ and as an example of what has been mentioned, a chimp can obtain the position $(x^* - x, y^*)$ by adjusting the values of the vectors $m = (1,1), a = (1,0), c = (1,1)$, while figure (b) indicates the expected locations of chimp’s in the 3D drawing.

2.2.2. The Exploitation Phase
Chimp are adept at exploring the victim’s location through the operations of command, stalking, blocking, then encirclement, and in general, predation is done by the attacker of the chimp. In order to mathematically sample the attack behavior of chimp’s, we will assume that the best available solution is for the first attacker and that the victim driver, barrier and stalker have a better knowledge of the location of the potential victim, and then four of the best solutions obtained so far are stored, and thus the rest of the chimp’s will be forced to update Their places according to the best site for chimp’s. These simulations are represented above by equations (6), (7) and (8) as follows:

\[ d_{\text{Attacker}} = |c_1 x_{\text{Attacker}} - m_1 x|, \quad d_{\text{Barrier}} = |c_2 x_{\text{Barrier}} - m_2 x|, \]
\[ d_{\text{Chaser}} = |c_3 x_{\text{Chaser}} - m_3 x|, \quad d_{\text{Driver}} = |c_4 x_{\text{Driver}} - m_4 x|, \]
\[ x_1 = x_{\text{Attacker}} - a_1 (d_{\text{Attacker}}), \quad x_2 = x_{\text{Barrier}} - a_2 (d_{\text{Barrier}}), \]
\[ x_3 = x_{\text{Chaser}} - a_3 (d_{\text{Chaser}}), \quad x_4 = x_{\text{Driver}} - a_4 (d_{\text{Driver}}), \]
\[ x(t + 1) = \frac{x_1 + x_2 + x_3 + x_4}{4} \]

2.2.3. Victim Attack
In the final stage of the chase, the chimp attacks the victim, and the operation ends once the victim stops moving. To mathematically represent the attack and hunt process, the parameter $f$ must be minimized, and we also observe that the variance range of $a$ is also minimized by the same parameter mentioned above. In other words, $a$ is a random variable in the range $[-2f, 2f]$, while the value of $f$ is minimized in
the iteration period, as mentioned previously. When the random values of a are in the period [-1,1], the next location for the chimp will be at any point between the current location and the victim site.

2.2.4. The Exploration Phase

The exploration process between groups of chimp is done by the position of the attacker, the barrier, the chaser and the chimp driver, and this process goes through two basic stages, which is the phase of divergence to search for victim and convergence when attacking the prey, and in order to sample the behavior of these two stages, we will use the vector a with a random value bigger than number 1 or less than The number -1, thus the search agent will be forced to turn away from the victim. Figure 3 shows that if the inequality \(|a| > 1\), then the chimp will be forced to dispersal in the environment to find better victim. Otherwise, the spread disparity would lead the chimp closer enough to the victim and a good catch [18].

![Figure 3](image)

Figure 3. Update the position of chimpanzees with respect to the effect |a| on him

2.2.5. Social Motivation

The social incentive of the chimp or called sexual motivation (grooming) pushes the chimp monkey in the final stage to give up its responsibilities in the hunting process, and thus the chimp searches for food in a chaotic manner. This behavior will ultimately avoid the chimp falling into the trap of the local optima and also help it alleviate the problem of slow convergence to solve all high-dimensional problems. To represent the aforementioned chaotic behavior, we assume that there is a 50% probability ratio to choose between a regular update locus mechanism and a chaotic sample of chimp position update during the optimization phase. This mechanism will be represented by equation (9) in the following figure, where \(\mu\) is a random number in [0,1].

\[
x_{\text{chimp}}(t+1) = \begin{cases} 
  x_{\text{prey}}(t) - a \cdot d & \text{if } \mu < 0.5 \\
  \text{Chaotic\_value} & \text{if } \mu \geq 0.5 
\end{cases}
\]

(9)

The following are the steps in the chimp improvement algorithm as follows:-

Step 1: Generating a elementary community of chimp.
Step 2: Generating the values of the elementary vector for \(a, c, m, f\).
Step 3: Calculate the position of each chimp.
Step 4: Divide chimpanzees randomly into independent groups until the stopping condition is met.
Step 5: Calculate the function of all fitness for each search element of chimp.
Step 6: For all iterations, the following are calculated:
   - Find the best search component = \(x_{\text{Attacker}}\)
• Find the second-best search component = \( x_{\text{Barrier}} \)
• Find the third-best search component = \( x_{\text{Chaser}} \)
• Find the fourth-best search component = \( x_{\text{Driver}} \)

**Step 7:** If the current iteration is less than the total iterations \( t < \text{MaxIter} \).

**Step 8:** Extracting a group of chimp and using the group’s strategy to update c, m, f, and then calculate a, d.

**Step 9:** For each chimp search object if \( \mu < 0 \cdot 5 \) and \( |a| < 1 \) update the current search object’s position with equation (2), otherwise \( |a| > 1 \) updates a random search element

**Step 10:** If \( \mu \geq 0 \cdot 5 \) update the current search position using equation (9).

**Step 11:** Update \( x_{\text{Attacker}}, x_{\text{Barrier}}, x_{\text{Chaser}}, x_{\text{Driver}} \).

**Step 12:** Calculate the new iteration \( t = t + 1 \)

**Step 13:** stop and return \( x_{\text{Attacker}} \).

3. **Conjugate Gradient Methods**

The conjugated gradient methods are part of the general gradient methods and are particularly useful in finding the smallest values of the multivariate functions, and although they need to perform longer calculations, on the other hand they do not need to store any matrix besides the ratio of their convergence is linear [19], and thus these methods are more commonly used in solving problems of large dimensions. Gradient are intended to methods to calculate the final value of a general, differentiable function with several variables. One of the types of conjugated gradient methods is the linear conjugated gradient method or what is known as the quadratic conjugated gradient method, which is used to shrink the convex quadratic function. The nonlinear conjugate gradient method, or what is known as the non-quadratic conjugated gradient method, is used to shrink general convex functions or nonlinear general functions [20, 21].

3.1. **Standard Conjugate Gradient Method**

The traditional conjugate gradient method is one of the most iterative methods for solving quadratic reduction problems [22].

\[
\min f(x) = \frac{1}{2} x^T G x - v^T x + c \tag{10}
\]

Where \( v \) is a vector, \( c \) is a constant value, and \( G \) is a positive-defined symmetric matrix of the type \( n \times n \). Equation (10) can be obtained equivalent as a system of linear equations as follows:

\[
G x = v \tag{11}
\]

This makes the only solution to equation (10) it’s the same (11) and thus the traditional conjugated gradient method can be considered either an algorithm for solving linear systems or a technique for finding the smallest value of the convex quadratic functions [20]. One of the noteworthy characteristics is that the conjugated gradient method It can generate a set of vectors having the conjugation property, where we can calculate the new direction \( d_{n+1} \) using the previous direction \( d_n \) and \( g_n \) the current gradient, and it is chosen so that it is a linear combination of \( -g_n \) (which represents the direction of the new gradient) and the vector \( d_n \) (represents the previous direction). Therefore, we do not need to know all the previous directions \( d_0, d_1, ..., d_{k-1} \) for the conjugate group, since \( d_{n+1} \) is related to all the previous directions, and it is considered the feature that makes this method require storage space and calculations a few write as follows:

\[
d_{n+1} = -g_{n+1} + \beta_{n+1} d_n \tag{12}
\]
Since $\beta_{n+1}$ represents a scalar quantity, which is specified so that $d_{n+1}$ and $d_n$ are conjugate to the matrix $G$, we choose the first search direction at the initial point $d_0 = -g_0$ (representing the extreme gradient direction) [4], as The convergence rate of the conjugate gradient methods is linear unless iterations are recovered [23], Figure 4. A flowchart of the standard conjugate gradient method is illustrated.

![Flowchart of the standard conjugate gradient method](image)

**Figure 4.** The standard conjugated gradient method

4. **Hybridization Chimp Optimization Algorithm ChOA**

In this paragraph, a modern method for solving high-scale optimization problems will be proposed, through a proposed new hybrid algorithm, by linking the evolutionary ideas of ChOA with the traditional ideas of the conjugated gradient algorithm (CGA), called ChOA-CG for short form. In this proposed algorithm, the process in each iteration was divided into two stages. In the first stage, randomness, velocity, and flexibility are used for the ChOA algorithm, and in the second stage, the conjugate gradient algorithm and the FR beta value are used. ChOA has its advantages over other meta-heuristic algorithms in searching for the top four locations driver, barrier, chaser and attacker, and they represent the four best solutions. The maximum benefit of this feature was achieved when performing hybridization and obtaining an amazing results for most of the standard test jobs. The flowchart in Figure 5. Represents the proposed algorithm for (ChOA-CG).
5. Numerical Results
To evaluate the performance of the proposed algorithms in solving optimization problems, the proposed algorithm ChOA-CG was tested, using (10) high-scaled functions in order to compare it with the algorithm of organed ChOA, and Table (1) shows the details of the test functions as well as the specific range, the limits upper and lower limits of each function, the number of iterations, where (500) iterations were used, and the dimensions that indicate the number of variables in the design.
As for the tables (2-5), it will clarify the results of the (ChOA-CG) algorithm and the results of the original (ChOA) algorithm, and through the comparison between the two algorithms, the success of the (ChOA-CG) algorithm is shown by improving the results of the ten test functions of high measure, which confirms the success of the process hybridization.

Table 2. Comparison of results between ChOA and ChOA-CG using the number of elements consisting of ((5)) elements and the number of repetitions 500

| Function | ChOA   | ChOA -CG |
|----------|--------|----------|
| F_1      | 3.2447 | 0        |
| F_2      | 0.24783| 0        |
| F_3      | 2710.1199 | 0 |
| F_4      | -5798.7602 | 0 |
| F_5      | 20.1694 | 0        |
Table 3. Comparison of results between ChOA and ChOA-CG using the number of elements consisting of ((10)) elements and the number of repetitions 500

| Function | ChOA      | ChOA-CG  |
|----------|-----------|----------|
| $F_6$    | 0.8832    | 0        |
| $F_7$    | -1.0312   | 0        |
| $F_8$    | 4.3387    | 0        |
| $F_9$    | 19.9654   | 8.8818e-16 |
| $F_{10}$ | 0.0014232 | 0.14841  |

Table 4. Comparison of results between ChOA and ChOA-CG using the number of elements consisting of ((20)) elements and the number of repetitions 500.

| Function | ChOA      | ChOA-CG  |
|----------|-----------|----------|
| $F_1$    | 5.5698e-05  | 0        |
| $F_2$    | 0.00016713  | 0        |
| $F_3$    | 7.582       | 0        |
| $F_4$    | -5858.0532  | 0        |
Table 5. Comparison of results between ChOA and ChOA-CG using the number of elements consisting of ((30)) elements and the number of repetitions 500.

| Function | ChOA          | ChOA-CG       |
|----------|---------------|---------------|
| F1       | 5.7218e-08    | 0             |
| F2       | 1.5142e-05    | 0             |
| F3       | 54.1029       | 0             |
| F4       | -5754.2164    | 0             |
| F5       | 11.485        | 0             |
| F6       | 1.5293e-05    | 0             |
| F7       | -1.0316       | 0             |
| F8       | 0.033116      | 0             |
| F9       | 19.9613       | 8.8818e-16    |
| F10      | 0.0013647     | 0.14841       |

6. Conclusions
The importance of the research lies in improving the performance of the chimpanzee algorithm (ChOA) by hybridizing it with one of the standard traditional methods, which is the Conjugate Gradient method. It is a proposed method for solving high-scale optimization problems, and thus researchers and specialists will be helped to take advantage of the proposed hybrid algorithm in solving such types of problems, in this paper the evolutionary algorithm was hybridized with one of the traditional algorithms, as it helped improve the performance of meta-heuristic algorithms and thus An increase in the speed of convergence, as well as contributed to improving the quality of the resulting solutions by increasing their exploration capabilities, and the numerical results also contributed to the ability of the hybrid
algorithms to solve various optimization problems of high scale, and the results of the proposed ChOA-CG algorithm were compared with the original ChOA algorithm. The same amazing solutions were obtained for most of the test functions, and this is what the research results showed.

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