

Article

## AGTO – SMA: A Hybrid Swarm Intelligence Optimization Algorithm

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**Abstract:** In this research, two types of intelligent algorithms were studied, namely the slime mould algorithm (SMA), which is a meta-heuristics intelligent algorithm that is a distinctive mathematical model, and the Artificial Gorilla Troop Optimization (AGTO), which is a meta-heuristics intelligent swarm algorithm whose model is based on exploitation and exploration. An improved algorithm called AGTO-SMA is a hybrid algorithm that uses two types of swarm intelligence and exploits the distinctive characteristics of each of them, where the two algorithms work together to produce an adequate mathematical model that can avoid falling into local solutions, as well as the speed of finding solutions with a minimum number of iterations and reaching the global optimal solution. In this study, an important fact that has not been highlighted by previous studies is that despite the progress in finding intelligent algorithms, they still fall short of achieving the optimal solution for most of the functions used in applications, and the issue of accuracy in finding solutions has not been discussed. Through the numerical results of the developed algorithm AGTO-SMA, this algorithm showed its superiority over other algorithms individually, its access to the optimal solution and the possibility of overcoming local solutions. Its approach speed was very high. It does not need a large number of elements of the swarm used for the algorithm if compared to its predecessors, which makes it an algorithm of great value in the field of optimization.

**Keywords:** Hybrid, Optimization, Heuristic Algorithm, Swarm Intelligence, Intelligent Technologies.

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### 1. Introduction

The issue of optimization is found everywhere in the world we live in and in all fields of science, engineering, computer science and economics, even in the daily routine, as well as the quest of companies to maximize profits and minimize costs and losses at the same time. Optimization has emerged as one of the branches of knowledge that searches and explores optimal solutions to any issue within a set of alternatives or can be taken to make vital decisions from a set of options. It is an active research field. The scientific and research boom has primarily motivated the development of highly efficient optimization algorithms[1]. The current development has pushed us to use heuristics and meta-heuristics algorithms such as the SCA[2] and IWO-SCA and BA[3],AOA[4] and CG-SCA[5]. The reason for using this type of algorithm is that it is easier to implement than classical algorithms. They do not need to find the gradient; local solutions can bypass them and be used in a wide range of disciplines [6][7]. Studies indicate that hybrid algorithms can revolutionize the field of optimization in particular and scientific research in general and can meet the challenge of optimality issues. This is what has been put in this study. Roger Flechter has described the field of optimization as (a surprising combination of theory and computation, along with research methods and precision) [8].

## Fundamental and Definition Concepts

**Optimization:** In mathematics, optimization is the process of determining the lowest or maximum value of a function with  $n$  variables, where  $n$  is any integer bigger than zero. In other words, optimization is the process of selecting the best option from a range of accessible choices.[9]

**Optimization Algorithms:** The variable  $x$  is first estimated using iterative methods, which then produce a series of iterations (Iterates) that end when they arrive at the best answer..[8]

**Optimization Method:** Large-scale, complex optimization problems can be solved with modern optimization techniques, which have become an essential tool for problem - solving across a variety of industries.

$$\min \text{ or } \max f(x) \quad ; x \in R^n \quad (1.1)$$

If  $f(x)$  is an objective function, and  $x$  is an  $n$ -dimensional real vector, These issues are referred to as unconstrained optimization problems. Constrained optimization problems are those that rely on constraints.[10]

$$\min \text{ or } \max f; x \in R^n$$

Subject to

$$\begin{aligned} c_k(x) &\leq (\geq) 0 & k = 1, 2, \dots, m \\ h_k(x) &= 0 & k = m + 1, \dots, l \end{aligned} \quad (1.2)$$

**Meta-heuristic Algorithm:** Traditional numerical methods had computational bottlenecks in solving complex optimization problems, so researchers had to rely on meta-heuristics algorithms. These modern algorithms have been developed to carry out exhaustive searches. meta-heuristics algorithms can be attributed to imitating the best features found in nature, especially the fittest selection in biological systems that have evolved by natural selection over millions of years [11][1].

## 2. Materials and Methods

### Slime Mould Algorithm (SMA)

Because it resembles a fungus and thrives in cold, damp environments, slime mold was formerly categorized as a fungus. The slime mold's active and dynamic stage is Plasmodium, the primary trophic stage. Because of its unusual and peculiar pattern, this organic matter can use several food sources simultaneously and construct a venous network to connect them. The processes below demonstrate the mathematical model: This organic matter looks for food, surrounds it, and secretes enzymes to digest it.

Step (1): Approaching the food

The slime mould can approach the food according to the smell in the air to express this behavior according to the following mathematical formula

$$x(t+1) = \begin{cases} x_b(t) + vb \cdot (w \cdot x_A(t) - x_B(t)) & t < p \\ vc \cdot x(t) & t \geq p \end{cases} \quad (1.3)$$

The following formula determines  $p$  where  $vc$  decreases linearly from 1 to 0.  $x(t)$  is the location of the slime mold,  $x_a(t)$  and  $x_b(t)$  are two randomly chosen individuals from the slime molds,  $w$  is the weight, and  $x_b(t)$  is the current location with the highest odour concentration currently present.

$$p = \tanh |s(k) - DF| \quad (1.4)$$

Where  $s(k)$  is the fitness,  $DF$  is the best fitness obtained for all iterations, the formula for  $vb$  is

$$vb = [-a, a] \quad (1.5)$$

$$a = \operatorname{arctanh} \left( -\left(\frac{t}{T-t}\right) + 1 \right) \quad (1.6)$$

The  $w$  formula is

$$w(\text{smell index } (l)) = \begin{cases} 1 + r \cdot \log \left( \frac{bf-s(k)}{bf-wf} + 1 \right), & \text{condition} \\ 1 - r \cdot \log \left( \frac{bf-s(k)}{bf-wf} + 1 \right), & \text{others} \end{cases} \quad (1.7)$$

$$\text{smell index} = \text{sort}(s)$$

Where  $r$  is a random value within the interval  $[0,1]$ ,  $bf$  denotes the best fitness in the current iteration, and  $wf$  denotes the worst fitness value obtained in the current iteration.

Step (2): Food wrapping

The search location can be updated based on the best location found using a mathematical formula, and the slime molds follow their patterns to search based on the quality of the food, increasing in areas where food concentration is guaranteed and decreasing in areas where food concentration is low.

$$x^* = \begin{cases} rand \cdot (ub - lb) + lb & , rand < z \\ \{x_b(t) + vb \cdot (w \cdot x_A(t) - x_B(t)) & r < p\} \\ vc \cdot x(t) & r \geq p \end{cases} \quad (1.8)$$

where  $r$  is a random value in the interval  $[0,1]$

Step (3): Holding the food

$vb$  oscillates randomly between  $[-a, a]$  and gradually approaches zero as the repetitions increase.  $Vc$  oscillates between  $[-1,1]$  and tends to zero [12][13].

#### SMA Algorithm

The steps of the algorithm can be summarized as follows:

S (1): Set the parameters (population size and maximum number of iterations)

S (2): Set up the slime mould locations

S (3): The number of steps is less than the maximum number of iterations

S (4): Determine the fitness of the slime moulds

S (5): Update *best fitness*,  $x_b$

S (6): Calculate  $W$  from equation (1.7)

S (7): Update  $p$ ,  $vb$ ,  $vc$

S (8): Update the locations using equation (1.3)

S (9): Return the best solution (*bestFitness*,  $X_b$ ) discovered.

S (10): End the steps when the stopping criterion is met, and the optimal solution is found. [12][13].

#### Artificial Gorilla Troops Optimizer (AGTO)

Like other monkeys, gorillas have feelings and establish strong family ties. They live in groups called troops, which are controlled by the silver man, who takes his name from the silver-colored hair that grows on his back during puberty.

Because different mechanisms were used for the optimization processes (exploration and exploitation), the artificial gorilla algorithm is based on the exploration and exploitation phases. In the exploration phase, there are three mechanisms: moving to a known location significantly improves search performance in exploitation, moving to the last gorilla increases the balance between exploration and exploitation, and moving to an unknown location increases exploration. All gorillas are regarded as potential solutions, and the silverback gorilla in the exploration phase is the best candidate solution in each optimization phase. The AGTO algorithm's optimization space comprises three different types of solutions, where  $x$  is the gorilla location vector and  $Gx$  are the gorilla location vectors generated at each stage. Ultimately, the silverback is the best solution in each iteration. If  $rand$ . The migration to a known site is chosen if  $rand < 0.5$ . Every mechanism gives the AGTO algorithm a unique capability. The algorithm can effectively monitor the entire problem space thanks to the first mechanism, perform better during AGTO exploration thanks to the second mechanism, and escape from local optimal spots is improved thanks to the third mechanism. The three mechanisms employed in the exploration phase were simulated using the following equation.

$$GX(t+1) = \begin{cases} (ub - lb) \times r_1 + lb & rand < p \\ (r_2 - c) \times x_r(t) + L \times H & rand \geq 0.5 \\ x(i) - L \times (L \times (x(t) - Gx_r(t)) + r_3 \times (x(t) - Gx_r(t))) & rand < 0.5 \end{cases} \quad (1.9)$$

$GX(t+1)$  is the location of the gorilla in the next iteration,  $x(t)$  is the current location of the gorilla,  $r_2, r_1$  are random values between 0 and 1,  $p$  is a parameter that must be

given a value before optimization and has a range between 0 and 1 and this parameter determines the migration mechanism to an undefined location,  $x_r(t)$  is a member (gorilla) randomly selected from the population,  $Gx_r(t)$  is the location of the randomly selected gorilla and C, L and H are calculated using the equations

$$C = F \times (1 - \frac{t}{T}) \quad (1.10)$$

$$F = \cos(2 \times r_4) + 1 \quad (1.11)$$

$$L = C \times l \quad (1.12)$$

$$H = z \times x(t) \quad \text{where } z = [-c, c] \quad (1.13)$$

$r_4$  the end of the exploration phase, the group formation process takes place, and the cost of all solutions is calculated if  $Gx(t) < x(t)$ , then the solution of  $Gx(t)$  is used as the solution of  $x(t)$ , so the best solution created at this stage is also the silverback.

Two methods are used during the exploitation phase: silverback and competition for adult females. The silverback gorilla is the leader of the group, makes all decisions, guides the group's movements, and points the gorillas in the direction of food sources. The following equation and the parameter  $c$  are used to calculate this strategy if  $c \leq w$ .

$$Gx(t+1) = L \times M \times (x(t) - x_{silverback}) + x(t) \quad (1.14)$$

$$M = (|\frac{1}{N} \sum_{k=1}^N Gx_k(t)|^g)^{\frac{1}{g}} \quad (1.15)$$

$$g = 2^l \quad (1.16)$$

where  $x(t)$  is the location vector of the gorilla, and  $x_{silverback}$  is the location vector of the silverback gorilla (the best solution). The second mechanism for the competitive exploitation phase of the adult female is  $c < w$ , where young gorillas reach puberty and fight with other male gorillas to expand their group in selecting adult females, and the following equation is used to simulate this behavior

$$Gx(k) = x_{silverback} - (x_{silverback} \times Q - x(t) \times Q) \times A \quad (1.17)$$

$$Q = 2 \times r_5 - 1 \quad (1.18)$$

$$A = \alpha \times E \quad (1.19)$$

$$E = \begin{cases} N_1, & \text{rand} \geq 0.5 \\ N_2, & \text{rand} < 0.5 \end{cases} \quad (1.20)$$

Where  $x_{silverback}$  is the silverback location vector (best solution),  $x(t)$  is the gorilla's current location,  $r_5$  is a random number,  $\alpha$  is a parameter that gives a value before the optimisation process, at the end of the exploitation phase, the population formation process takes place, and the cost of all solutions is calculated. If  $Gx(t) < x(t)$ , the solution  $Gx(t)$  is used as the solution of  $x(t)$  and the best solution obtained among all populations is considered to be silverback [14][13].

#### AGTO Algorithm

The steps of the algorithm can be summarized as follows:

- S (1): Initialize the random population, population size N, maximum number of iterations T and parameters
- S (2): Calculate the fitness values of the gorilla
- S (3): If the stopping condition is not met, go to Step (4)
- S (4): Update C using equation (1.10)
- S (5): Update L using equation (1.11)
- S (6): Exploration phase for each gorilla
- S (7): Update Location using equation (1.9)
- S (8): Calculate gorilla fitness values
- S (9): If GX is better than X, replace them.
- S (01): Assign the best location  $x_{silverback}$
- S (11): Exploitation phase for each gorilla
- S (12): If  $|c| \geq 1$  then
- S (13): Update the gorilla's location using equation (1.14)
- S (14): Otherwise, update the gorilla's location using equation (1.17)

- S (15): Calculate the fitness values of the gorilla  
 S (16): If the new solutions are better than the previous ones, replace them  
 S (17): Set the best  $x_{silverback}$  location  
 S (18): Return ,  $x_{bestFitness}$   
 S (19): End the steps when the stopping metric is met, and the optimal solution is found [14][13].

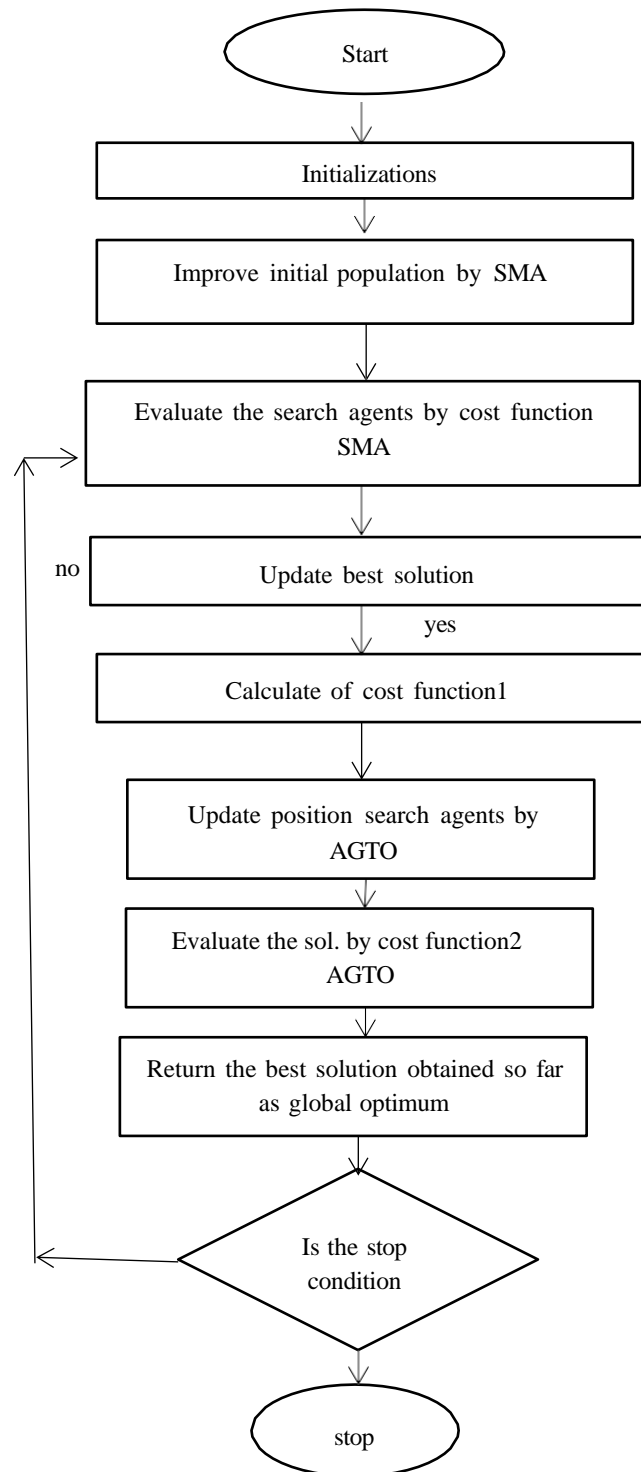
#### **Proposed Hybrid Algorithm AGTO- SMA**

This algorithm is proposed based on the SMA slime mould algorithm, which is a meta - heuristics algorithm whose mathematical model is based on the foraging behavior of this fungus and used in the development and hybridization of the AGTO gorilla troop swarm algorithm, which is a meta-heuristics algorithm inspired by nature and which uses a distinct mathematical system, namely exploration and exploitation. Making these two algorithms work together with an optimized model and algorithm results in an algorithm with high specifications that can avoid falling into the trap of local solutions as well as reaching the optimal solution in addition to the speed of approaching the solution in record time and using the minimum number of swarm elements and the minimum number of iterations, The hybridization process starts by initializing random initial solutions and then the SMA algorithm optimizes and evaluates these solutions and then uses these optimized solutions as an initial population for the AGTO algorithm to optimize them and select the best among them and so these solutions are re-optimized and evaluated using SMA and then using AGT together to reach the optimal solution.

#### **Work steps for the AGTO-SMA hybrid algorithm**

- 1- Initial community generation.
- 2- Finding the initial solutions using SMA.
- 3- Evaluate the solutions using the SMA fitness function.
- 4- Optimizing these solutions using the AGTO algorithm.
- 5- Evaluate the solutions using the AGTO fitness function and select the best solution.
- 6- Comparing the best solution with the new one and choosing the best one.
- 7- Is the number of iterations complete? If the answer is no, perform steps 3 -8; otherwise, stop.

As shown in **Figure 1**, the flowchart of the AGTO-SMA hybrid algorithm illustrates the key steps involved in the optimization process.



**Figure 1.** Flow Chart Hybrid method (SMA-AGTO) Algorithm

### The Main of Hybridization

is to use two types of algorithms with specific characteristics; linking and combining these characteristics gives the hybrid algorithm high flexibility in dealing with the countries in which it is used; using two algorithms of the type of intelligent swarms would generate a unique system that can give excellent results, and this is what has been communicated using this hybridization AGTO-SMA.

### 3. Results

The numerical results were found as shown in Table 1 where 11 functions [2] were used for optimization measurement with the number of elements of a swarm of 30 and the number of iterations of 500 .

**Table 1.** Comparison of the Hybrid Algorithm AGTOA-SMA with the algorithms SMA and AGTO at the number of elements =30 and the number of iterations =500

FUNCTION	SMA	AGTOA	AGTOA-SMA
F1	0.00E+00	0.00E+00	0
F2	3.77E-191	1.1788E-203	0
F3	0.00E+00	0.00E+00	0
F4	9.48E-233	1.0248E-211	0
F5	6.38E-03	2.11E-09	1.56E-27
F6	8.12E-03	3.003E-22	0
F7	8.69E-05	3.97E-04	2.44E-26
F8	-1.26E+04	-636.3498	-636.3498
F9	0.00E+00	0.00E+00	0
F10	8.88E-16	8.88E-16	8.88E-16
F11	0.00E+00	0.00E+00	0

### 4. Discussion

After applying the hybrid algorithm to a set of measurement functions for optimization problems and obtaining a set of numerical results, these results showed the superiority of the hybrid algorithm over the other two algorithms, as it was able to overcome the local solutions and reach the global optimal solution in most functions or obtain the best minimization of the used states as well as its speed in solving with the least number of swarm elements and the least number of iterations used [15].

The results from applying the AGTO-SMA hybrid algorithm demonstrate its superiority over the individual SMA and AGTO algorithms. This improvement is evident in its ability to avoid local solutions and converge faster to the global optimum. Similar studies, such as those by Khalaf and Mitras (2021), have shown that hybrid algorithms, particularly those combining different swarm intelligence methods, tend to outperform their individual counterparts in terms of both accuracy and convergence speed. Additionally, the hybrid approach used in this study significantly reduces the number of iterations needed to reach optimal solutions when compared to traditional optimization techniques, as evidenced by the results in Table 1. The results align with findings from Yang and Deb (2010), who observed that combining multiple metaheuristic algorithms enhances exploration and exploitation capabilities. This is a key factor contributing to the fast convergence observed in our experiments [16].

### 5. Conclusions

In this paper, the AGTO and SMA algorithms were studied. These two algorithms were observed to have poor performance in terms of falling into local solutions and not reaching the optimal solution for most of the functions. When trying to hybridize these two algorithms and produce an improved hybrid algorithm AGTO-SMA, it showed its superiority over the other algorithms when compared. It reached the optimal solution very quickly and with excellent results, as shown by the numerical results.

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