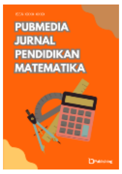

Jurnal Pendidikan Matematika Vol: 2, No 2, 2025, Page: 1-11

A Novel Modified Swarm Intelligence Algorithm Combining Black Widow Optimization Algorithm and Pelican Optimization Algorithm to solve Global Optimization Problems

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DOI: https://doi.org/10.47134/ppm.v2i2.1480
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Received: 22-01-2025
Accepted: 02-02-2025
Published: 27-02-2025

Abstract: In this paper, an improved algorithm called BWOA-POA is a hybrid algorithm based on the Black Widow Algorithm (BWOA), which is an algorithm inspired by nature and has excellent specifications in addition to another algorithm, the Pelican Swarm Optimization Algorithm (POA), which is a smart swarm algorithm that is also inspired by nature When studying these two algorithms, we find that each of them has some weaknesses and that they fall into local solutions in some countries and this is what prompted us to develop the hybrid algorithm BWOA- POA, which was able to avoid falling into the trap of local solutions and reach the global optimal solution, as the numerical results proved its superiority over the others and the speed of reaching the solution in record time with the least number of swarm elements and the least number of iterations, as this developed algorithm BWOA-POA was applied to the optimality measurement functions and the results were excellent if compared with its predecessors, This model is one of the most powerful models and can be applied in solving engineering problems and all studies that need to reach the best solutions from minimizing or maximizing the models presented.

Keywords: Swarm Intelligence, Optimization, Meta-heuristic Algorithm, Modified, Intelligent Technologies

Introduction

Optimization exists in almost all fields of science and it plays a vital role in the field of complex issues where optimization presents certain models that provide a simplified representation of reality from some mathematical formula where formulas allow understanding complex systems, solving problems and obtaining valuable information that supports making the right intelligent decisions where optimization uses algorithms to find the most appropriate solution to the issues at hand The issue of optimization, hybridization and development for algorithms is a well-known and traded area today and it determines the extreme points for states whether the highest value or least value where developed algorithms become a critical tool to manage and take The study and research in the field of intelligent optimization is the interest of a large number of researchers and this is what prompted us to create a hybrid algorithm based on two types of algorithms, meta–heuristic and nature-inspired algorithms, many researchers have preceded us with several studies, but they were sometimes deficient and some optimization issues, The proposed study is based on previous algorithms and studies, including those presented by several researchers (Sayed Ali Marjalali and others)example SCA , CGSCA,IWOSCA with several algorithms that were a starting point for the creation of the next generation of developed mathematical models and many of the evening of event algorithms and swarm intelligence and developmental calculations have been put forward in several previous studies.

Methodology

Black Widow Optimization Algorithm (BWOA)

The black widow is a type of poisonous spider that weaves its webs in trees, inhabits forests and swamps, and feeds on insects such as crickets, beetles, and butterflies. The following steps illustrate the mathematical model of the algorithm

Step (1): Movement

The following equation illustrates the spider's movement

$$x_k(t+1) = \begin{Bmatrix} x^*(t) - m x_{r_1}(t) & if\ rand\ \le 0.3 \\ x^*(t) - \cos(2\pi r)\, x_k(t) & in\ other\ wise \end{Bmatrix} \quad \ldots(1)$$

where $x_k(t+1)$ is the new location and indicates the movement of the spider, $x^*(t)$ is the best location found so far, m is a random number, r_1 is a random number between 1 and the maximum population size, $x_{r_1}(t)$ is the first location as $k \neq$, r is a random number defined in the interval [-1,1], $x_k(t)$ is the current location.

Step (2): Pheromones

Because well-fed females make more silk than hungry females and because male spiders are more receptive to the pheromones of well-fed females, pheromones are crucial in spider mating. The pheromone rate is calculated using the following formula.

$$pheromone(k) = \frac{fitness_{max} - fitness_{(k)}}{fitness_{max} - fitness_{min}} \ldots(2)$$

Where $fitness_{max}$and $fitness_{min}$ are the best and worst fitness value in the current generation respectively, $fitness_{(k)}$ The pheromone vector in equation (2) contains the appropriate fitness in the interval [0,1], if the pheromone rates are low in female spiders less than or equal to 0.3, it is replaced by another one with the following equation.

:

$$x_k(t) = x_*(t) + \frac{1}{2}[x_{r1}(t) — 1\sigma * x_{r2}(t)] \qquad \ldots(3)$$

Black Widow Algorithm Steps

The steps of the algorithm can be summarised as follows:

Step (1): Initialise the initial community.

Step (2): The number of steps is less than the maximum number of iterations.

Step (3): Initialise the random parameter m and α such that $0.4 \le m \le 0.9$ و $-1.0 \le \alpha \le 1.0$

Step (4): Update the spider's motion using equation (1)

Step (5): Calculate the pheromone for each location using equation (2)

Step (6): Update sites with low pheromone values using equation (3)

Step (7): Determine the value of x_{new} for the new site

Step (11): If $x_{new} < x_*$ then

Step (12): $x_* = x_{new}$

Step (13): End the steps when the stopping criterion is met, and the optimal solution is found.

Pelican Optimization Algorithm POA

It is an algorithm based on the mathematical model inspired by a flock of pelicans in nature, where this algorithm is presented, which depends on several calculations, namely inspiration and the behavior of the pelican during hunting. The large pelican has a long beak with a bag in a ring to catch and swallow prey. The pelican likes to live in groups; its flock usually consists of about 100 birds. Its food consists mainly of fish, frogs, crustaceans, and turtles, and they often work together to hunt. If the pelican hunts, it begins by locating the prey and diving for it from 10 to 20 meters. A lot of water enters the beak during hunting, and the beak pulls its head forward to ingest the prey before expelling the extra water. The pelican is a proficient hunter due to its clever hunting behavior and technique. The strategy model indicated above served as the primary source of inspiration for creating the suggested model.

The mathematical model of the pelican algorithm POA

Each bird is valuable for the optimization issue based on its position in the search space since the algorithm is based on the flock's elements, which are represented by the pelican. Each element is thought of as a potential solution. Equation No. 4 uses the top and lower bounds of the problem to randomly initialize us, the community's constituent elements.

$$x_{i,j} = l_i + rand * \left(u_j - l_j\right) \quad ,i = 1,2,\dots,n\,, \qquad j = 1,2,\dots,m \qquad (4)$$

N is the number of community members, m is the number of variables for the problem and is a random number between zero and one, where li is the lower limit and ui is the upper limit of the variables of the problem, and $x_{i,j}$ is the value of the jth variable as determined by the ith candidate solution.

The members of the community are renewed in the proposed working model using the population matrix eq.(5) where each row represents the proposed solution, and each column represents the proposed value of the variables of the problem

$$X = \begin{bmatrix} x_1 \\ \dots \\ x_i \\ \dots \\ x_N \end{bmatrix}_{N*m} = \begin{bmatrix} x_{1,1} & \dots x_{1,j} & \dots & x_{1,m} \\ \dots & \dots & & \dots \\ x_{i,1} & x_{i,j} & \dots & x_{i,m} \\ \dots & \dots & & \dots \\ x_{N,1} \dots & x_{N,j} \dots & & x_{N,m} \end{bmatrix}_{N*m} \quad (5)$$

The evaluation of the POA algorithm is based on each of the candidate solutions, where X in the population matrix is the pelican and xi is the ith pelican. In addition to the problem's stated target function, each pelican member represents a potential solution. Equation (6) displays the objective function vector, which is used to determine the values utilized in the objective function.

$$F = \begin{bmatrix} F_1 \\ \dots \\ F_i \\ \dots \\ F_N \end{bmatrix}_{N*1} = \begin{bmatrix} F(x_1) \\ \dots \\ F(x_i) \\ \dots \\ F(x_N) \end{bmatrix}_{N*1} \quad (6)$$

The objective function for the ith candidate solution is fi, and the objective function vector is F. The behavior of the pelican strategy when assaulting and hunting prey is simulated by the suggested model. The procedure is conducted in two steps to update the candidate solutions, which are

1. Exploration (moving towards the prey)
2. Exploitation (opening the wings on the water surface)

The first stage: Exploration stage

After figuring out where the prey is, the swans move in that direction. According to the swan strategy model, the search space is scanned and several regions are found. The crucial element is that the prey's position is randomly produced inside the smallest search space, enhancing the ability to explore various search space regions. The power of precise investigation in problem-solving is increased by this search space constraint. Equation (7) provides a mathematical simulation of the aforementioned ideas and the swan technique for approaching the prey's position.

$$x_{i,j}^{p} = \begin{cases} x_{i,j} + rand * (p_j - I * x_{i,j}), & F_p < F_i \\ x_{i,j} + rand * (x_{i,j} * p_j), & else \end{cases}; \quad (7)$$

Hence, according to the first stage, $x_{i,j}^{p}$ is the new state for the ith pelican in the jth dimension. I is a random integer that can be either 1 or 2. fp is the value of the objective function, and pj is the prey's position in the jth dimension. One or two parameter I numbers can be selected at random. This parameter, which has a number that can guide this element to more recent regions of the search space, is selected at random for every iteration. Consequently, the power of exploration to precisely search the search space is influenced by the parameter I. The goal function in this algorithm accepts the value of the updated location; this kind of update is known as the update Effective.

$$x_i = \begin{cases} x_i^{p_1}, & F_i^{p_1} < F_i \\ x_i, & else \end{cases}; \qquad (8)$$

Where $x_i^{p_1}$ is the new state of the ith pelican and $F_i^{p_1}$ is the value of the objective function based on phase 1.

The second stage is the exploitation stage (winging on the water surface)

At this point, the swans move the fish up by spreading their wings on the water's surface after they have reached it, and they then gather the prey in the neck bag. By using this tactic, more fish are caught in the region where the swan flock attacked. By simulating this swan behavior, the suggested model converges to more advantageous locations inside the fishing region. Additionally, this procedure improves the formal model's exploitation potential and local search power. From a mathematical perspective, in order to get closer to a better result, the algorithm needs to look at the points close to the swan location. Equation (9) simulates this swan swarm behavior statistically while fishing.

$$x_{i,j}^{p_2} = x_{i,j} + \mathrm{R} * \left(1 - \frac{t}{T}\right) * (2 * rand - 1) * x_{i,j} \qquad (9)$$

"Where $x_{i,j}^{p_2}$ is the new state of the ith pelican in the jth dimension based on phase 2, R is a constant and equals 0.2, and $\mathrm{R} * \left(1 - \frac{t}{T}\right)$ is the neighborhood radius $x_{i,j}$. t is the iteration counter, and T is max iteration. the coefficient $\mathrm{R} * \left(1 - \frac{t}{T}\right)$ represents the diameter radius of the neighborhood of the members of the population to be searched and close to each element to converge to the best solution, this coefficient is effective on the power of exploitation to approach the optimal global solution in the initial iterations. The value of this coefficient is large, and as a result, the area is larger around each element. With the increase in the work of the algorithm, the coefficient $\mathrm{R} * \left(1 - \frac{t}{T}\right)$ decreases, leading to smaller radii of the neighborhood of each individual of the population with smaller and more accurate steps that can approach with solutions closer to the global solution or to the global solution completely, on the concept of use at this stage, the effective update is also used by accepting or rejecting the new swan site that was designed in equation" No. (10)

$$x_i = \begin{cases} x_i^{p_2} , & F_i^{p_2} < F_i \\ x_i , & else \end{cases} ; \qquad (10)$$

where $x_i^{p_2}$ is the new status of the ith pelican and $F_i^{p_2}$ the value of the objective function based on phase 2.[10]

Steps of the Pelican Algorithm POA[10]

Step 1: Initialize the initial population.
Step 2: Update the swarm elements using the objective function.
Step 3: Update the best solutions based on the objective function.
Step 4: Use the next iteration.
Step 5: Repeat the different steps of the algorithm based on equations (7-10) until the end of the full implementation of the iterations.
Step 6: Obtain the best candidate solution.

Proposed Algorithm BWOA-POA This algorithm BWOA-POA

was proposed based on the Black Widow Algorithm BWOA inspired by nature, which simulates the behavior of a type of spiders that has a mathematical model with a high performance capacity. This algorithm was developed based on the Pelican Swarm Algorithm POA, which is one of the natural swarms that has a mathematical model that has been proposed and used in solving optimization problems. The developed algorithm BWOA-POA is a hybrid model that combines the characteristics of the two algorithms mentioned above, which makes it a very effective mathematical model as it is based on two types of super-intuitive algorithms, where the initial community is prepared and then the Pelican algorithm improves the proposed solutions and then evaluates them. After that, these candidate solutions are received using the Black Widow Algorithm BWOA, where the other improves the values of the solutions until reaching the optimal global value. Choosing algorithms with high efficiency and ability to find solutions made the developed algorithm very capable and excellent in reaching the global solution in the shortest time and the least number Repetitions as well as the possibility of exceeding local solutions. Presenting this model contributes to supporting the solution of all optimization problems that search for the global solution. The following are the steps of the algorithm as well as its flowchart figure (1).

Steps of the proposed algorithm BWOA-POA.

1. Initialize the initial population.
2. Evaluate the population elements using the objective function POA.
3. Select a set of candidate solutions based on the objective function POA.
4. Improve the solutions using the equation ( )
5. Improve the candidate value using the BWOA model.
6. Evaluate the solutions using the objective function BWOA.
7. Select the best candidate solutions.
8. Compare the best solution with the new solution and choose the best between them.
9. If the number of iterations is less than the allowed, perform steps (2-7), otherwise stop.

The goal of hybridization

It is known that each algorithm has certain weaknesses, but when combining more than one algorithm, the proposed model will be an excellent model and can overcome the weaknesses. This is what happened during the development of this model, where the two algorithms were exploited together, both the Black Hope Algorithm BWAO and the Pelican Algorithm POA, and made them work together. The process can be likened to a car engine that uses a turbo system to reach the best performance. The characteristics of the two algorithms were exploited together to reach this developed model.

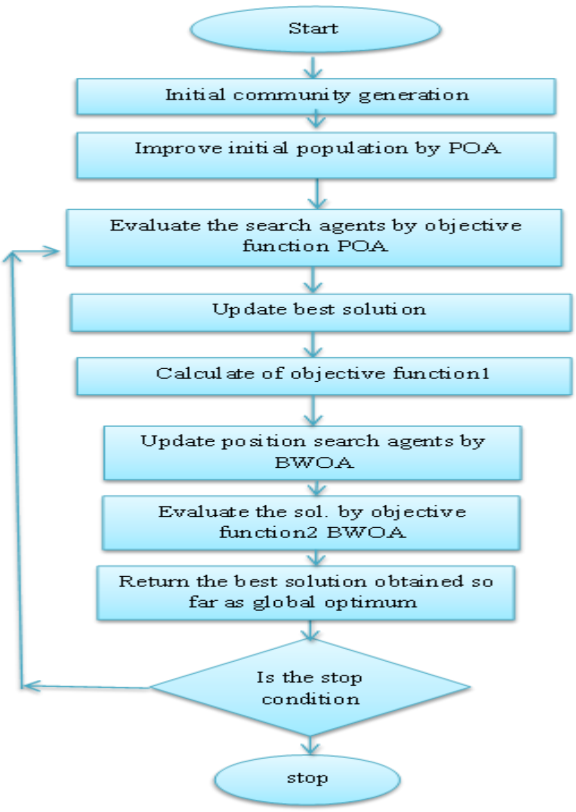

Figure 1. Flow Chart Modified method (GWOA-POA) Algorithm

Result and Discussion

The numerical results were found as shown in Table (1) where ten functions[3] were used for optimization measure with the no. of elements of a swarm N= 30 and the number of iterations I= 500 .

Table 1. Comparison of the modified algorithm BWOA-POA with BWOA and POA at the number of elements

FUNCTION	BWOA	POA	BWOA-POA
F1	0.00E+00	1.07E-102	**0**
F2	4.58E-277	2.17E-51	**0**
F3	0.00E+00	4.97E-109	**0**
F4	2.53E-266	1.48E-54	**0**
F5	28.9745	26.9044	**28.9273**
F6	6.5937	0.00E+00	**0**
F7	1.73E-04	8.16E-05	**3.55E-09**
F9	0.00E+00	0.00E+00	**0**
F10	8.88E-16	4.44E-15	**8.88E-16**
F11	0.00E+00	0.00E+00	**0**

Discussion

In this research paper, a unique developed algorithm called BWOA-POA was presented and applied to 10 functions specific to measuring optimization. The numerical results that we obtained in Table No. (1) from the application of this proposed mathematical model were compared. The results proved, upon comparison, that this model is superior to other models and avoids falling into the trap of local solutions and reaching the global optimal solution for most of the countries used. It also proved its effectiveness with the least number of swarm elements and the least number of iterations during application.

Conclusion

What was reached through this research paper is that the development of intelligent algorithms would present a strong and effective model that can solve many complex models that cannot be solved using conventional or classical algorithms. This is clear through comparing the results that were reached. The developed algorithm that was presented, BWOA-POA, has proven its superiority and reached the global solution in the shortest time, the fewest number of iterations, and the least number of swarm elements used in the algorithms.

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