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Fuzzy logic-based Northern Goshawk algorithm optimization and hybridization of the Northern Goshawk and Black Widow algorithms

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ABSTRACT

Innovations and new methods for solving long and difficult mathematical puzzles are essential to advances in many branches of research and knowledge. As a result, experts have proposed intelligent algorithms, which are determined by their ability to quickly and efficiently answer the most difficult mathematical puzzles. To achieve the greatest results in this worksheet, we used two different strategies. The first method involved integrating the Goshawk Optimization algorithm (NGOA) with fuzzy logic (FL), while the second method was based on two hybrids, the first by linking communities and the second by linking the equations between the Black Widow Optimization algorithm (BWOA) with the Northern Goshawk optimization algorithm (NGOA). Then we applied both techniques to the basic functions of ten algorithmic functions to get the results.

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1. Introduction

The Meta-Heuristic Algorithm (MHA) Algorithms inspired by natural species [1 - 3], as well as observations of animals that live in swarms [4] or solitary and their foraging behavior. Scientists created mathematical models in the form of algorithms to simulate these items, which were then utilized to solve optimization issues to find the best solution.

The Northern Goshawk Optimization Algorithm (NGOA) is a predatory bird that feeds on other living species including rabbits [5 - 6], mice, fish [7], and other birds [1 - 4]. He created a mathematical model of the goshawk in the form of an algorithm that replicates the goshawk's hunting activity. The bass bird has a two-stage hunting process, the first of which is to detect the prey and the second of which is to chase the prey [12], this method was used to solve optimization issues and find the best solution.

The Black Widow Optimization Algorithm (BWOA) It's an algorithm based on black widow spiders' distinctive mating behavior. This approach contains a one-of-a-kind stage called cannibalism. Species with poor fitness are

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eliminated from the circuit at this step, leading in early convergence and increased efficiency in finding optimum solutions to problems [5 - 8].

Fuzzy Logic (FL) Fuzzy sets [12 - 13], which are sets without categorical limitations, are used in theories and procedures as a suitable replacement for the classical set, which no longer satisfies the needs of the new mathematical and logical understanding in our present scientific thought. The Azerbaijani researcher Lotfi Zadeh from the University of California invented this idea in 1965 with the goal of improving data processing by using a more human-like style of thinking in data programming [19]. When dealing with complicated problems, precision may not always be important but may be critical when working with basic systems [20 - 23].

In this paper, we employed two alternative approaches. The Northern Goshawk Optimization Algorithm (NGOA) and fuzzy logic (FL) were combined in the first method, while The Black Widow Optimization Algorithm (BWOA) and The Northern Goshawk Optimization Algorithm were combined in the second (NGOA). To get the findings, we next applied both strategies to the 10 core algorithmic functions.

2. The Northern Goshawk Optimization Algorithm (NGOA)

Linnaeus initially described the northern goshawk in 1758, and it is a medium-sized bird. A raptor that hunts both large and small birds, as well as perhaps very small birds of prey, is the northern goshawk. Rats, rabbits, squirrels, even foxes and raccoons are among his favorite foods. The northern goshawk may be found across Eurasia and North America, and the male is much larger than the female. The male measures 46 to 61 cm in length, 89 to 105 cm in wingspan, and 780 grams in weight. The female, on the other hand, is between 58 and 69 cm long, weighs 1220 g, and has a wingspan of between 108 and 127 cm. Figure 1 is a photograph of a northern goshawk. The northern goshawk's hunting method is divided into two stages: in the first, it travels quickly towards the prey after spotting it, and in the second, it pursues it down in a brief pursuit [24], [25].

FIGURE 1 *THE NORTHERN GOSPEL*.

When hunting and capturing prey, the northern goshawk uses a devious strategy. The major source of motivation for developing the program was mathematical modeling of the previously outlined technique. This technique simulates two primary actions of northern goshawks: (1) prey recognition and assault, and (2) a two-stage chase and escape procedure. When hunting in the wild, the northern goshawk's tactics and behavior are visible. The northern goshawk (NGOA) in the early stages of random hunting, picking prey and attacking it quickly. Due to the random selection of prey in the search space, this level improves the ability to explore. This step leads to a thorough

examination of the search space to find the best location. Figure 2 This figure shows the behavior of the northern goshawk (NGOA) at this stage, including prey selection assault.

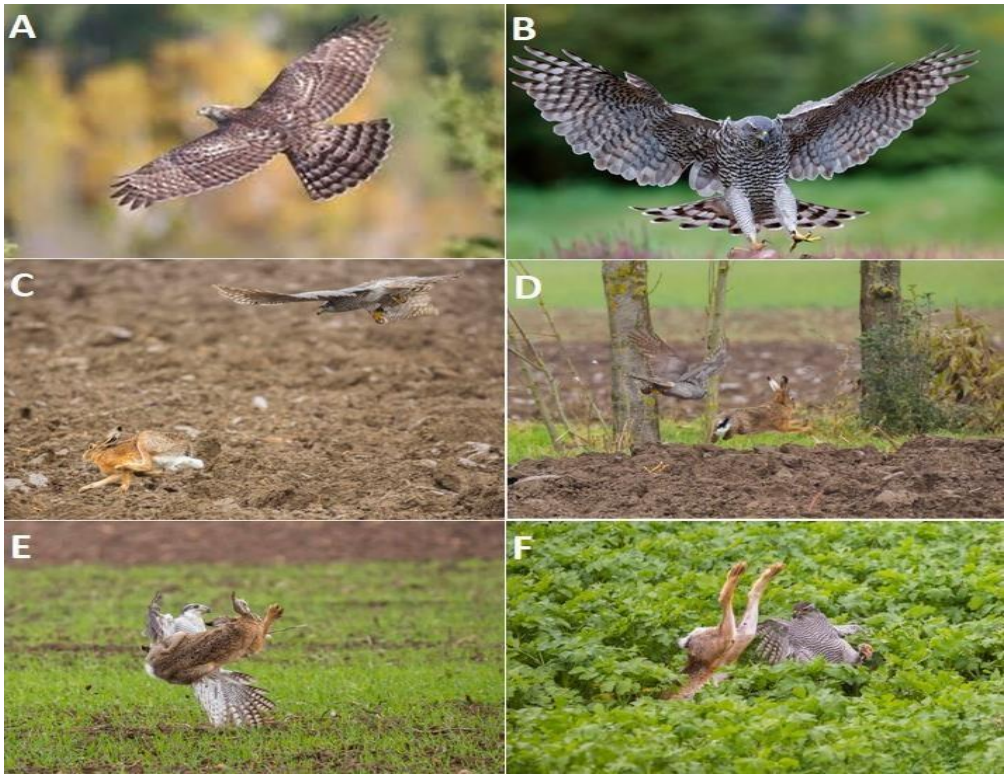

FIGURE 2 NORTHERN GOSHAWK HUNTING BEHAVIOR: (A) SCAN THE WILD FOR PREY, (B-C) ATTACK PREY, (D-E) FOLLOW-UP STAGE, AND (F) HUNT.

$$P_n = X_i, n = 1,2,\dots,K, i = 1,2,\dots,n-1,n+1,\dots,K \quad (1)$$

$$x_{n,k}^{new,p1} = \begin{cases} x_{n,k} + r(p_{n,k-Ix_{n,k}), F_{p_n} < F_n} \\ x_{n,k} + r(x_{n,k-p_{n,k}), F_{p_n} \geq F_n} \end{cases} \quad (2)$$

$$x_n = \begin{cases} x_n^{new,p1}, F_n^{new,p1} < F_n \\ x_n, F_n^{new,p1} \geq F_n \end{cases} \quad (3)$$

where P_n is where the ith northern goshawk hunts for prey., F_{p_n} is the value of its objective function, i is a chance natural number that falls between [1, K], $x_n^{new,p1}$ is the updated situation for the newest suggestion., $x_{n,k}^{new,p1}$ is its jth dimension, $F_n^{new,p1}$ is the objective function value based on the first phase of the NGO, and r is a random integer in the range [0, 1], where I is a chance number, which may be either 1 or 2.

$$x_{n,k}^{new,p2} = x_{n,k} + R(2r-1)x_{n,k} \quad (4)$$

$$R = 0.02\left(1 - \frac{t}{T}\right) \quad (5)$$

$$x_n = \begin{cases} x_n^{new,p2}, F_n^{new,p2} < F_n \\ x_n, F_n^{new,p2} \geq F_n \end{cases} \quad (6)$$

where t is the iteration counter, T is the maximum number of iterations, $x_n^{new,p2}$ is the new status for ith proposed solution, $x_{n,k}^{new,p2}$is its jth dimension, $F_n^{new,p2}$ is its objective function value based on second phase of NGO

3. The Black Widow Optimization Algorithm (BWOA)

The southern black widow, sometimes known as the "black widow," is a very deadly species of spider. Females may be identified by their characteristic black and red coloring, and after giving birth, they will occasionally consume their spouse. These animals only exist in North America. Humans are seldom killed by its poison [26]. The males and females of this species of spider have various appearances, but in every instance the females are the most recognizable owing to their glossy, black and red bodies with patterns on the underside of the abdomen that resemble the form of an hourglass and are used to warn some animals. Males are smaller than females, have fewer red or pink markings, and are paler in color. on their backs. Males are one to two months old, and females live for around three years. Women are referred to be widows because of this. The United States, South Asia, Australia, Africa, and a significant portion of South America are among the numerous temperate locations of the world where this variety of spider may be found. They can be discovered in places that are primarily dark, like bathrooms, huge holes, sheds, garages, basements, and regions with a lot of vegetation [27]. Fly, mosquito, locust, beetle, larval insects, and other spiders that get tangled in their webs are all consumed by black spiders. Its teeth are then pushed into the prey, where they inject digestive enzymes to disintegrate it and then suck the fluids. The prey is first captured in the net's threads. According to studies and research, the venom of black widow spiders—which are among the most dangerous spiders—is 15 times more potent than that of a snake bite. Fortunately, these spiders only bite people when they feel threatened, and female spider bites are the most harmful to people's health. The strongest sort of neurotoxic emitted by female black spiders when they bite their prey is known as latrotoxins, and it is this venom that gives black widow spiders their name (Latrodectus). Alpha-latrotoxin, which targets sufferers' nerve systems, is the most poisonous form. According to Jessica Crab of the University of Massachusetts, the toxin alpha-latrotaxone travels to the pre-synaptic region, the site of contact between the synapse and muscle cells or other neurons, and then inserts itself into a membrane when a black widow bite you. It hurts a lot when the neurotransmitters in all the neuron's vesicles are released as a result. Contrary to common opinion, most bite victims have a variety of symptoms, but seldom die as a result [28]. The young, the old, and the sick, however, are the groups most at risk. Within minutes, the agony starts, and it spreads fast to other body areas. Numerous symptoms are brought on by this bite, including elevated blood pressure, severe back and stomach discomfort, nausea, and excessive perspiration. Diaphragmatic paralysis results in breathing difficulties, muscular weakness, headaches, increased salivation, numbness, and sleeplessness. While other symptoms might linger for many days, the pain lasts for eight to twelve hours. A serum that helps lessen harm from black widow bites should be noted. Some people may not experience the agony of a black widow's bite, which normally feels like a pin prick. In these cases, an ulcer will subsequently grow from a little red lump. If the sting is in the upper body, the person will typically experience pain in the chest area, and if it is in the lower body, the person will feel agony in the abdomen. To counteract the poison's effects, a specific medication is administered. However, because this medication has the potential to trigger a severe allergic reaction, it must be taken with caution. The first couple of days of these symptoms' recovery might occasionally persist for weeks. It is advised to wear protective clothes when traveling in locations where this type of spider dwells and to avoid sitting beneath tree trunks, shrubs, or other moist areas

where these spiders are likely to hide in order to prevent getting bitten by a black widow. When a black widow bite you, it is recommended to travel to the nearest hospital, but you must administer some first aid to perhaps lower the danger of infection. After applying a tiny piece of ice to the afflicted region for 10 minutes, elevate the towel for another 10 minutes, then repeat the process. Black widow in figure (3)

Black widow algorithm mathematical formula:

$$w_1 = e.s_1 + (1-\beta).s_2 \qquad (7)$$

$$w_2 = e.s_2 + (1-\beta).s_1 \qquad (8)$$

Where it s_1, s_2 represents the parents and represents w_1, w_2 the children, or it β is the matrix that contains random numbers.

4. Fuzzy Logic (FL)

Theories and methods that employ fuzzy sets, which are sets without categorical bounds, as a viable replacement for the classical set that no longer satisfies the needs of the new mathematical and logical understanding in our modern scientific thought. This idea was invented in 1965 by the Azerbaijani scientist Lotfi Zadeh of the University of California. He did this by implementing a more human-like style of thinking in data programming, which would improve its utility for data processing. If precision is crucial while working with basic systems, it is often superfluous and not necessary when working with complicated problems [29 - 31].

4.1 Fuzzy Set (FS)

It is a group whose boundaries are ambiguous and not sharp (Crisp), and its boundaries cannot be established with clarity and precision, i.e., in which the marginal logic (belongs or does not belong), since ambiguity permeates every realistic activity. If X represents the universal set, then the ordered pair set is represented by the fuzzy set A of X . It has the following form in definition:

$$A = \{x\ , \mu_A(x)\}$$

for each element x in X, where $\mu_A(x)$ is the membership function of the element x in A and that:

$$\mu_A(x) \in [0,1]$$

4.2 Membership Function (MF)

The concept of fuzzy logic is based on a basic issue, which is that there is no total affiliation to groups or elements, or vice versa. The set, and the basic condition for this function is that its range is between zero and one, and it has multiple forms of it:

- Triangular Function: Mathematical formula for it

$$\mu(x) = \begin{cases} 0 & ; \quad x \le a \\ \dfrac{x-a}{b-a} & ; \quad a \le x \le b \\ \dfrac{c-x}{c-b} & ; \quad b \le x \le c \\ 0 & ; \quad c \le x \end{cases} \qquad (9)$$

The parameters of the function are a, b, and c. a and c stand for the lists of the trigonometric function, while b stands for the vertices of the triangle.

- Trapezoidal Function: Mathematical formula for it

$$\mu(x) = \begin{cases} 0 & ; \quad x \le a \\ \dfrac{x-a}{b-a} & ; \quad a \le x \le b \\ 1 & ; \quad b \le x \le c \\ \dfrac{d-x}{d-c} & ; \quad c \le x \le d \\ 0 & ; \quad d \le x \end{cases} \tag{10}$$

where a, b, c, and d are the function's parameters, and a and d stand in for the figure's lower and higher vertices, respectively.

- Gaussian Function: Mathematical formula for her

$$\mu(x) = e^{-\frac{(x-c)^2}{2\sigma^2}} \tag{11}$$

The parameters c and σ respectively represent the upper vertex of the figure and the distance of the edges from the center of the figure.

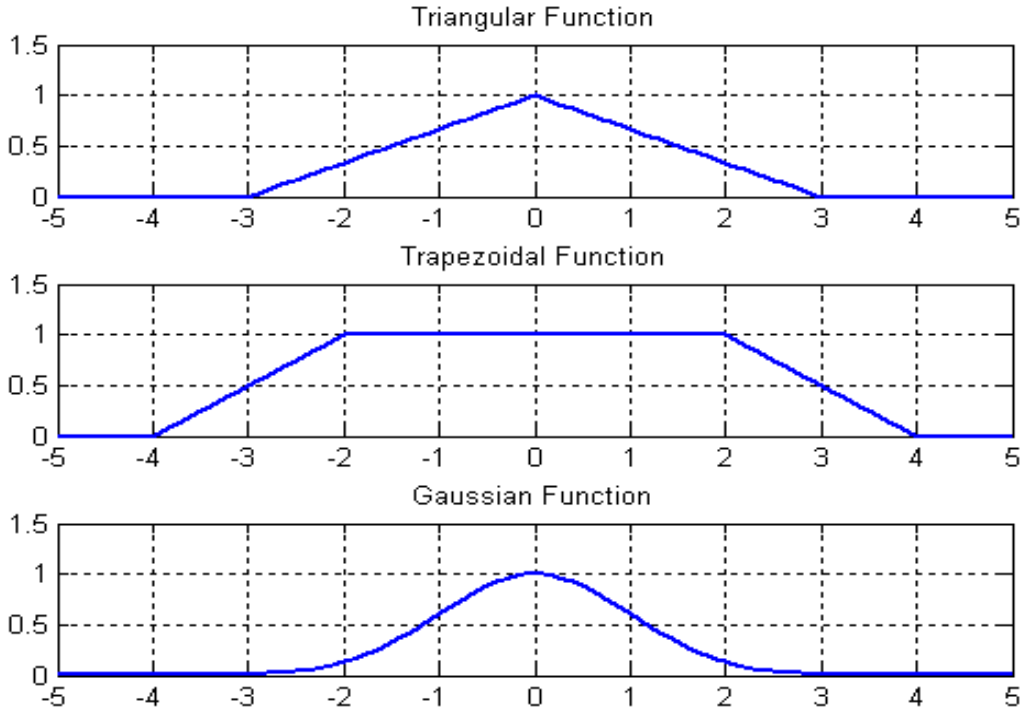

FIGURE 4

4.3 Fuzzy Inference Systems (FIS):

These are (fuzzy-rules) based systems. A fuzzy inference system is a general name for a system that uses fuzzy thinking to transform an input space into an output or output space. Ambiguity is always present in any realistic process, and this ambiguity may arise as a result of the interpretation of the input data and the rules used to

describe the relationship between the information-rich properties in those entries, and the fuzzy logic provides us with a fuzzy inference system that resembles human deduction capabilities, and this system represents the entire process of making decisions using ambiguity logic. There are two main types of fuzzy inference systems:

- **Fuzzy inference of the Mamdani type**: In this model, the (Defuzzified) process is applied to the fuzzy group resulting from the sum of the fuzzy groups for each base in the (Consequent) part, as the output is represented in the form of fuzzy sums, based on the (If-Then) rule as follows: R_i : $IF\ x\ is\ A_i\ THEN\ \ y\ is\ B_i \quad i = 1,2, \dots\dots, K$

A_i : The parameters represent precedence (Antecedent).

B_i: Represents the set of dependent products (Consequent).

Precedence is the initial part (the IF part) of the fuzzy rule, and the function represents the final part (then part) of the fuzzy rule.

- **Fuzzy inference of the Takagi-Sugeno type**: In the Mamdani model, a model based on expert knowledge is used, while the Takagi-Sugino model is defined in which precedents are defined as in the Mamdani model, and the dependents are defined as a linear function close to the input variables, as this model generates fuzzy rules from the input and output data set. Y) is calculated by taking the average weights of the bases, and the output is represented in the form of fixed values as in the following formula:
  $Ri: IF\ x\ is\ A_i\ \ THEN\ \ Y_i\ =\ a_i^T x + b_i \qquad i = 1,2, \dots\dots K$
  a_i: The vector parameter of function.
  b_i : Adjustment scale.
  Also, the weighted average of the bases is calculated through the following equation:

$$Y = \frac{\sum_{i=1}^{K} \beta_i(x) y_i}{\sum_{i=1}^{K} \beta_i(x)} = \frac{\sum_{i=1}^{K} \beta_i(x)(a_i^T x + b_i)}{\sum_{i=1}^{K} \beta_i(x)} \qquad (12)$$

$\beta_i(x)$: Membership Function

5. A Proposed Business Model

The basic concept of the work is divided into two main stages. The first stage involves combining Goshawk Optimization (NGOA) and fuzzy logic to achieve better results than Goshawk Optimization (NGOA) alone. Fuzzy logic (FL) works by limiting the range of values to those between zero and one and by indicating the degree to which each value belongs. The second part of the work depends on creating a hybrid with two parts. The first hybridization is by linking the 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 by linking the equations by taking the equation of velocity for the first algorithm and linking it with the equations of the second algorithm. Correlation between the northern Goshawk optimization algorithm (NGOA) and the black widow optimization algorithm (BWOA), with the use of the black widow optimization algorithm (BWOA) as a goshawk optimization (NGOA) algorithm. We achieved the best results when we used the ten basic functions of the approved algorithms [17 - 20] shown in the table:

No.	Function	NGO	FNGO	NGO_BWOA1	NGO_BWOA2
F1	Sphere	4.0186e-179	7.9000e-211	0	0
F2	Schwefel 2.22	2.8778e-93	4.2493e-105	7.3281e-271	0
F3	Schwefel 1.2	8.4859e-51	0	0	0
F4	Schwefel 2.21	2.013e-77	2.8388e-106	4.3181e-272	0
F5	Step	1.3907e-08	5.2559	0	0
F6	Quartic	2.1051e-04	1.9455e-05	4.2796e-05	0

F7	Rastrigin	0	0	0	0
F8	Ackley	4.4409e-15	1.9540 e-15	8.8818e-16	0
F9	Griewank	0	0	0	0
F10	Penalized	0.2808	8.4094 e-06	5.0011e-09	0

No.	Name	Function	D	Range
F1	sphere	$f_1(x) = \sum_{i=1}^{n} x_i^2$	30	$[-100,100]$
F2	Schwefel 2.22	$f_2(x) = \sum_{i=1}^{n} \lvert x_i \rvert + \prod_{i=1}^{n} \lvert x_i \rvert$	30	$[-10,10]$
F3	Schwefel 1.2	$f_3(x) = \sum_{i=1}^{n} (\sum_{j=1}^{n} x_j)^2$	30	$[-100,100]$
F4	Schwefel 2.21	$f_4(x) = -\sum_{i=1}^{n} (x_i \sin\left(\sqrt{\lvert x_i \rvert}\right))$	30	$[-500,500]$
F5	Step	$f_5(x) = \sum_{i=1}^{n} (\lfloor x_i + 0.5 \rfloor)^2$	30	$[-100,100]$
F6	Quartic	$f_6(x) = \sum_{i=1}^{n} i x_i^4 + random[0,1)$	30	$[-1.28,1.28]$
F7	Rastrigin	$f_7(x) = -\sum_{i=1}^{n} [x_i^2 - 10\cos(2\pi x_i) + 10]$	30	$[-5.12,5.12]$
F8	Ackley	$f_8(x) = -20\exp\left(-0.2\sqrt{\frac{1}{n}\sum_{i=1}^{n} x_i^2}\right.$	30	$[-32,32]$
F9	Griewank	$f_9(x) = \frac{1}{4000}\sum_{i=1}^{n} (x_i - 100)^2 - \prod_{i=1}^{n} \cos\left(\frac{x_i - 100}{\sqrt{i}}\right) + 1$	30	$[-600,600]$
F10	Penalized	$f_{10}(x) = \frac{\pi}{2}\{10sin^2(\pi y_1) + \sum_{i=1}^{n-1} (y_i - 1)^2 \times [1 + 10sin^2(\pi y_i + 1)] + (y_n - 1)^2\} + \sum_{i=1}^{30} u(x_i, 10,100,4)$	30	$[-50,50]$

6. Conclusion

We conclude from this working paper that algorithms that do not give satisfactory results to the solution can be optimized and get the best results by including optimizations such as mutual information or other optimizations, as well as by creating a hybrid algorithm to get the best results from each algorithm separately.

We suggest combining black widow algorithm with north buzzer optimization method and mutual information or chaos map or creating a combination of fuzzy logic and north bass optimization algorithm with mutual information.

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