A Survey on Grey Wolf Optimizer

Shahnawaz Ali
Department of Computer Science
Gurukul College of Engineering and Technology
Kota, India
shahaligauri@gmail.com

Ankush Sharma
Department of Computer Science
Gurukul College of Engineering and Technology
Kota, India

Swati Jadon
Department of Computer Science
Gurukul College of Engineering and Technology
Kota, India

***Abstract*—the following survey describes the basics of greywolf-optimization and significant modifications done in the past few years. We divided the review of previous work into three parts; in the first part, we explained the work in which new parameters are defined. In the second part, we explained the work in which new concepts are proposed and control parameters are estimated. In the third part, we explained the work in which GWO is combined with other nature-inspired algorithms.**

Keywords—grey-wolf-optimizer, optimization, Nature-inspirealgorithm.

I. GREY-WOLF-OPTIMIZER ALGORITHM

Initially Mirjalili [1] was proposed GWO algorithm which defines how a grey wolf behaves socially. This behavior of grey wolves includes tracking, approaching, chasing, encircling and attacking the prey. They belong to the dog like family known as Canidae family. They can be recognized by strong tooth, fluffy feathers and have hunting behavior with a group of 5 to 12 wolves that is generally a middle sized group. The GWO can be scaled as follow:

Alpha-wolf is the group chief who is generally liable for decision making such as tracing task, hunting, stalking, sleeping place, exploration, exploitation etc. both the male and female grey wolf has the opportunity to become a leader. It is also called as the dominant wolf because it orders and the group follows. The important thing to know about the alpha wolf is that it is not the strongest but it should be best in activity management of the group.

Beta-wolf is a junior wolf that assist alpha wolf in leadership and taking the right decisions for the group. If accidentally the alpha wolf dies or becomes aged, the beta-wolf is the proper candidate to being an alpha-wolf. It is a helper to alpha and care for the group. It should pay respect to the alpha wolf and command other wolves to do the same. Beta wolf conveys the alpha's command into the group and provide a response as an acceptance to the alpha-wolf.

Delta-wolf same as the beta-wolf, the delta wolf also assists the alpha-wolf. They are a level higher than omega-wolf and provide the information to alpha and beta-wolves. The deltawolves are grouped as follows:

Scout wolf: watch the boundaries.

Sentinels wolf: protects the group.

Senior or older wolf: former alpha or beta wolves.

Hunter wolf: helps alpha-wolf and beta-wolf in hunting.

Caretaker wolf: caretaker of injured weak and ill wolves.

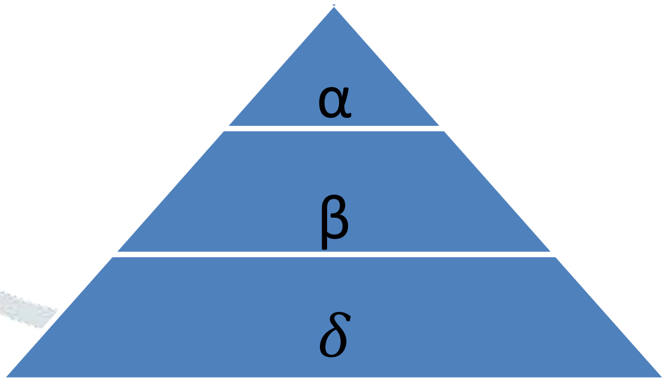

Fig. 1. Family of Grey-wolf.

II. MODEL CALCULATION AND GWO ALGORITHM

In this section, the social ranking, exploration, encircling, and exploitation are explained mathematically followed by the GWO algorithm.

A. Social ranking:

For the mathematically model the social ranking of the wolf when designing GWO, the $alpha_w$ is considered as fittest solution followed by $beta_w$ and $delta_w$ as second and third-best solutions respectively. These three solutions can be permanent as a basic group of wolves. [2]

B. Encircle the prey:

Initially, the wolves circumscribe or encircle the prey on the time of hunting.

The process of hunting the prey can be described by the following equation [1]:

$$\vec{D} = |C_{cof} \cdot \vec{w}_{prey}(itr) - \vec{w}_{gw}(itr)| \quad (1)$$

$$\vec{w}(itr+1) = \vec{w}_{prey}(itr) - A_{cof} \cdot \vec{D} \quad (2)$$

Here $\vec{A}_{cof}$ and $\vec{C}_{cof}$ are coefficient vectors, $\vec{w}_{prey}$ is prey's position vector, $\vec{w}_{gw}(itr)$ position vector for grey wolves and itr is indicating the present iteration. According to Equation 2 the grey-wolves decreases the distance to the prey.

The distance depends on D and A in which A reduces smoothly, and the distance from the prey is denoted by D. As the itr increase, wolves come nearer to prey than earlier. Now we can say that they surround their prey because their initial position is randomly determined. [3]

The coefficient vectors $\vec{A}_{cof}$ and $\vec{C}_{cof}$ can be finding out by the equations as follows:

$$\vec{A}_{cof} = 2\vec{a} \cdot \vec{r}_{1A} - \vec{a} \quad (3)$$

$$\vec{C}_{cof} = 2 \cdot \vec{r}_{2c} \quad (4)$$

Where $\vec{r}_{1A}$ and $\vec{r}_{2c}$ are random-vectors having the range of [0, 1] and |a| reduces in a linear way from 2 to 0.

(5)

itr=(itr+1)

$$\vec{w_1} = \vec{w}_{\alpha,wol} - \vec{A}_{cof1} \cdot \vec{D}_{\alpha,wol} \quad (6)$$

end while

return $\vec{w}_{\alpha,wol}$

$$\vec{w_2} = \vec{w}_{\beta,wol} - \vec{A}_{cof2} \cdot \vec{D}_{\beta,wol} \quad (7)$$

III. Literature Review

$$\vec{w_3} = \vec{w}_{\delta,wol} - \vec{A}_{cof3} \cdot \vec{D}_{\delta,wol} \quad (8)$$

The swarm intelligence based algorithms are unable to give the exact solution to the problem. These algorithms always use hit and trial method and give an approximate solution. "All the algorithms provide the same results if applied to the bunch of problems," says free lunch theorem. So the possibility is fittest always there to improve the existing algorithm. GWO is also a recently developed swarm intelligence algorithm so the modifications are possible. To improve in standard GWO algorithm many variants are recommended to improve the exploration and development capabilities of the algorithm. Those modified parameters are given as follows:

Here, $\vec{w}_{\alpha,wol}$, $\vec{w}_{\beta,wol}$, $\vec{w}_{\delta,wol}$ are position vectors of three possible solutions and $\vec{A}_{cof1}$, $\vec{A}_{cof2}$, $\vec{A}_{cof3}$ are coefficient vectors. The remaining parameters can be defined as follows:

$$\vec{D}_{\alpha,wol} = |\vec{C}_{cof1} \cdot \vec{w}_{\alpha,wol} - \vec{w}| \quad (9)$$

$$\vec{D}_{\beta,wol} = |\vec{C}_{cof2} \cdot \vec{w}_{\beta,wol} - \vec{w}| \quad (10)$$

$$\vec{D}_{\delta,wol} = |\vec{C}_{cof3} \cdot \vec{w}_{\delta,wol} - \vec{w}| \quad (11)$$

1. Defining new control parameters in GWO.
2. Estimating the available control parameters and defining new concepts in GWO.
3. Combining the GWO algorithm with other nature-inspired algorithms.

Here, $\vec{C}_{cof1}$, $\vec{C}_{cof2}$, $\vec{C}_{cof3}$ are coefficient vectors.

D. Exploitation:

Generally, when the prey stops walking, the grey wolf will attack it. We will decrease the value of |a| as the grey wolf

Grey-wolves start searching for the prey when the next iteration starts, to attack again on the prey. In this iteration the grey-wolf repeatedly searches for the next most suitable solution alpha amongst other grey-wolves. They repeat this process until the stopping criteria is completed. [4]

C. Hunting:

When the grey-wolf group discovered the situation of the prey then, the group is led by the $alpha_w$, the $beta_w$, the $delta_w$ to enclose the prey [2]. Here we are taking the location of the prey which is known already. So as a key group, Keep the three most suitable solutions obtained so far, and update the position of each wolf in the group accordingly. The equations for situation refurbishing are given below:

$$\vec{w}(iter+1) = \frac{w_1+w_2+w_3}{3}$$

come closer to the prey. |A| the range of change is also represented by | a |.

There can be two conditions arises first is if |A|'s value is lesser than 1 then the alpha-wolf attack on the prey. Second is if |A|'s value is greater than 1 then it can be assumed that the alpha wolf is far away from prey or get injured or tired. Here $\vec{C}_{cof}$ and 'a' are major parameters that are adjusted. We can define the value of 'a' using: |a|=[2-2*((1)/maxiteration], reduce in a linear way from 2 to 0.

As the above description, GWO algorithm illustrated in the following algorithm.

GWO Algorithm

Assign the inhabitants of grey wolf W_i , (i=1 to n)

Assign a, A_{cof} & C_{cof}

Estimate the fitness of each search agent from Equation 6, 7, 8.

while itr < max number of iteration **do for** every search agent **do**

upgrade search agent's present location.

the most suited position can be calculated from Equation 5

end for upgrade a, A_{cof} in Equation 3 and C_{cof} in Equation 4 estimate the fitness of all search agents

upgrade $\vec{w}_{\alpha,wol}$ in 6, $\vec{w}_{\beta,wol}$ in 7, $\vec{w}_{\delta,wol}$ in 8

A. Defining new control parameters in GWO

In 2016 S. Eswaramoorthy [5], present research on parameter selection based on grey wolf optimization for SVM. This paper tunes the SVM classifier with the help of GWO. In this paper important feature are extracted from collected data and classified using SVM classifier. They use metaheuristic optimization technique to adjust the classifier parameter. The optimally adjusted classifier parameter minimizes the error because of the manual elucidation. It minimizes the risk of human perception and repeated visual diagnosis.

In 2016 Asmaa H. Sweidan [6] presented a research paper in which they propose a system according to the microscopic image of fish-gills, the degree of water pollution is classified as a biomarker. They research on the GWO and case-based reasoning model to check the quality of water. They introduced a bio-inspired optimized classification model to check the quality of water.

In 2017 Heidari [7] presented research on an efficiently redesigned grey wolf optimizer with Levy flight for optimization task. It solves either global or real optimization problem. It increases the efficiency of GWO, levy flight and greedy selection techniques are combined with the modified stalking phases.

In 2018 Wendong Gai [8] proposed a new improved grey wolf optimization (IGWO) which avoids local minimization and premature convergence. They presented a non-linear control parameter depend on cos( ) to guarantee the fast convergence rate of late iteration. They also introduce the genetic algorithm in combination with IGWO. The proposed algorithm gives superior results in comparison against original GWO and GA.

B. Estimating the available control parameters and defining new concepts in GWO:

In 2015 Pranjali Rathee [9] proposed a new algo to find the solution of image registration with the use of a grey wolf optimizer algorithm. Image registration techniques are used for the integration of various images. The collected pictures are combined into a composite image which contains important information. The following equation defines the proportionality criterion:

$$number\ of\ agents = log_2(img\ size\ in\ kilobyte) \qquad (12)$$

In 2015 E. emary [10], presented the work on feature subset selection approach using GWO. It checks the data and discards noisy, unnecessary, excessive data and concurrently optimize the performance of classification. The GWO suggests a group of the accuracy-based fitness function to find optimal feature subset.

In 2016 Ali Madadi and Mehmood M. Mohseni [12], proposed an algorithm to optimally control the DC motor using GWO algo. It adjusts proportional integral derivative controller parameter in DC motor which controls a significant problem in the control field. This algorithm is designed and utilized for a dc-motor drive to find the global optimum tuning of PID controller parameter.

$$PID = k_p + \frac{k_i}{s} + k_d s \qquad (13)$$

In 2018 Li, Zewn and He [13] proposed a new discrete grey wolf optimizer (DGWO) to resolve bounded knapsack problem. As the result, it shows that the converging speed of DGWO is quicker and gives finer result in comparison to other algorithms. According to DGWO, the crossover scheme of the GA is offered to intensify its local search capability, and infallible clarifications treated by restoration and the optimization technique depends on the greedy scheme, which could make sure both the effectiveness and speed up the convergence.

$$p_{ij} = b_j * \frac{q_{ij} - lb}{ub - lb} + 0.5 \qquad (14)$$

Where q_{ij} represent the position X_i in jth dimension. p_{ij} represents the potential solution Y_i in jth dimension.

C. Combining the GWO algorithm with other nature-inspired algorithms:

In 2016 Vikram Kamboj [14], proposed a new hybrid PSOGWO method to solve unit commitment problem. They used swarm intelligent based particle swarm optimization algorithm. Using that technique they proposed the solution for the unique area unit commitment difficulty focused on the fourteen bus operation, thirty bus operations and ten generating unit models. They define the following steps:

- 1st step: fix the swarm and set up the solution space.
- 2nd step: evaluate the fitness of every bit.
- 3rd step: Upgrade personal and universal best results.
- 4th step: selecting the best position among the search agent's present position and upgrade the position of alpha, beta and delta-wolves with the help of GWO algorithm.
- 5th step: assign position of alpha as a final-position of the swarm.
- 6th step: go to 2nd step & revise until the stopping condition arrived.

In 2016 Mittal [10], find out and exponential function and proposed modified GWO for global engineering optimization for the decay of throughout iteration.

In 2017 Xu [2], proposed IGWO combined with cuckoo search. It has a stronger global search ability in comparison to others. This CS-GWO algorithm may avoid falling into the local optimum and jumping out of the local optimum in a highly dimensioned dataset.

In 2018 X Zhang [15], proposed a unique hybrid algorithm based on biogeography based optimization (BBO) and GWO, named as HBBOG. They removed the deviation operator and merged the differential deviation operator into immigration operator, to increase the global search ability in BBO. In the paper, on the place of initial migration operation, a multi migration operation takes place that enhances the local search ability.

References

[1] Sayedali Mirjalili, Sayed Mohammad Mirjalili and Andrew Lewis. Grey wolf optimizer. Advances in engineering software, 69:46-61, 2014.

[2] Hui Xu, Xiang Liu, and Jun Su. An improved grey wolf optimizer algorithm integrated with cuckoo search. In 2017 9th IEEE international conference on intelligent data acquisition and advanced computing systems: technology and applications (IDAACS), volume 1, pages 490493. IEEE, 2017.

[3] GM Komaki and Vahid Kayvanfar. Grey wolf optimizer algorithm for the two-stage assembly flow shop scheduling problem with release time. Journal of Computational Science, 8:109-120, 2015.

[4] Nitin Mittal, Urvinder Singh, and Balwinder Singh Sohi. Modified grey wolf optimizer for global engineering optimization. Applied Computational Intelligence and Soft Computing, 2016:8, 2016.

[5] Sathish Eswaramoorthy, N Sivakumaran, and Sankaranarayanan Sekaran. Grey wolf optimization-based parameter selection for support vector machines. COMPEL-The international journal for computation and mathematics in electrical and electronic engineering, 35(5):15131523, 2016.

[6] Asmaa Hashem Sweidan, Nashwa El-Bendary, Aboul Ella Hassanien, Osman Mohammed Hegazy, and AE-K Mohamed. Grey wolf optimizer and case-based reasoning model for water quality assessment. In The 1st International Conference on Advanced Intelligent System and Informatics (AISI2015), November 28-30, 2015, Beni Suef, Egypt, pages 229-239. Springer, 2016.

[7] Ali Asghar Heidari and Parham Pahlavani. An efficient modified grey wolf optimizer with levy flight for optimization tasks. Applied Soft Computing, 60:115-134, 2017.

[8] Wending Gai, Chengzhi Qu, Jie Liu, Jing Zhang. An improved grey wolf algorithm for global optimization. The 30th Chinese control and decision conference, CCDC 2018, pages 2494-2498. IEEE, 2018.

[9] Pranjali Rathee, Ritu Garg, and Sonal Meena. Using grey wolf optimizer for image registration. International Journal of Advanced Research in Science and Engineering, 4(4):360-364, 2015.

[10] Eid Emary, Hossam M Zawbaa, Crina Grosan, and Abul Ella Hassenian. Feature subset selection approach by grey-wolf optimization. In AfroEuropean Conference for Industrial Advancement, pages 1-13. Springer, 2015.

[11] Susheel Joshi, Jagdeesh chand Bansal. Grey wolf gravitational search algorithm. International workshop on computational intelligence, IWCI 2016, pages 12-13, IEEE, 2016.