A Systematic Literature Review- SLR On Recent Advances And Variants Of Grey Wolf Optimization

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Abstract: A grey wolf optimization algorithm is a newly developed metaheuristic algorithm. GWO has given a better solution to the optimization problem as compare to other swarm intelligence. It is a very simple and easy to implement this algorithm. It is considered as balanced in exploitation and exploration. GWO has a few parameters that why researches use this algorithm to solve the optimization problem. In this research a systematic literature study is carried out for studying about grey wolf optimization algorithm and its several models like hybrid, modified etc. Focus of this research is to deep investigate about Grey wolf optimization algorithm and find out issues in it.

Keywords: GWO, Metaheuristic, Optimization

1. INTRODUCTION

Grey wolf optimization was developed by Mirjaali in 2014 base on the leadership hierarchy and hunting mechanism of Grey Wolf in nature. Grey wolf belong to the Canidae family. Grey wolf consider the top of the food chain. Grey wolf lives in the pack. The pack of the grey wolf divided into different categories like alpha, beta. Omega, delta. Grey wolf has a very strict dominant social hierarchy. Alpha is the leader of the group. Alpha takes all decisions like where they live, how to hunting. Alpha is not the strongest one but the best one to manage the whole group. The second level is beta, beta is the subordinator of the alpha, beta helps to alpha take decision and looking for other groups activate. Beta manages the disciple of the group. If alpha passes away or old then beta becomes alpha (male or female). Beta fellow the alpha instruction and command the other lowest level wolf in the group. One of the more and lowest parts of the group is omega. Omega is the scapegoat in the group. Omega is the last one to eat food. It like omega is not important in the group but it has been facing the internal fight in the group. Omega also the babysitter wolf in the group. The last one group member is delta. Delta wolves responsibly to looking at the boundaries and feel any danger inform the group. These days' meta-heuristic methods are very useful to solve the problem. GWO one of the meta-heuristic algorithms. GWO applied to the different optimization problems. Numerical performance of GWO to compare with other population-based algorithms i.e. Particle swarm optimization, Gravitational search algorithm, and Differential evolution algorithm with the benefit of employing control parameters. Due to simplicity Grey wolf optimization gets more attention, and it has been given the better solution of the optimization problems. The population-based algorithm, such as the Genetic algorithm and Particle swarm optimization, as the development of search space length, Grey wolf optimization algorithm faces many challenging problems. For example, the GWO algorithm is naturally a little bit slower than an illustrative stochastic population-based algorithm (e.g., the whale optimization algorithm (WOA) [1]. When handling a uni-modal problem. In addition, GWO can simply obtain trapped in local optima when solving complicated multimodal problems. So if we solve the problem we found the best way to optimize the problem called the solution space. Every point in the search space given the one possible solution. A grey wolf optimization algorithm looks superior solution between a numbers of possible solutions demonstrated by one point in the search space. Looking for a solution for extreme (minimum or maximum) in search space. At times may be well-defined, but typically we know only some point in search space. In the procedure of applying GWO to fine the best solution. The problem is that search, not an easy way it's very complicated. But we can use the many methods to find out a possible solution like a Grey wolf optimization algorithm and so on. GWO is the newly developed algorithm. GWO has given a better optimization solution and solves the many optimization problems. GWO algorithm divided into three-part like alpha, beta and omega also this three-part are perform in mathematically step to solve the optimization problem.

2. LITERATURE STUDY METHODOLOGY:

A Systematic Literature Review has been used for this research. It is considered as a proper method to record significant focal points in the specific research range for investigating and analyzing. The flow of research will be consisting of the following factors as shown in figure 1.

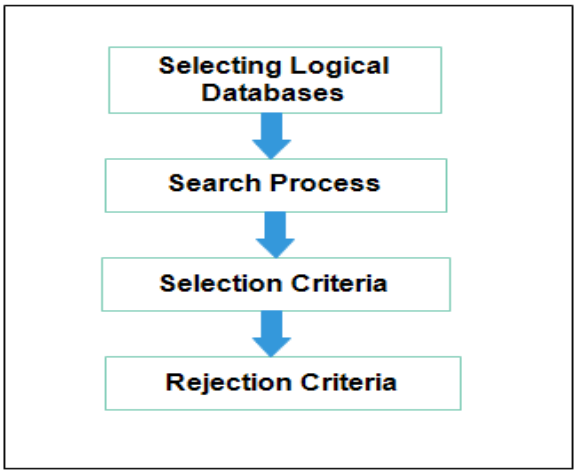

Figure 1: *Steps for SLR*

2.1 Selection Criteria

A strong research paradigm for the picking and dismissing of research articles is characterized. Six different parameters are portrayed for ensuring the correctness of the suitable reactions of our research questions. The research work will be picked on the reason of these parameters as given underneath.

2.1.1 Logical Databases:

Four logical research databases (for example IEEE, ELSEVIER, SPRINGER, also, ACM) with a particular ultimate ob-

jective for completing the research. These logical research databases' most extreme outcomes with respect to our point also, we have chosen the necessary article by means of one-self characterized the procedure depicted beneath. Year-wise range from "2013–2017" for the determination of research articles from our chose coherent databases is also utilized. Various Keywords for choosing articles various logical operators like AND OR are moreover utilized for making our inquiry precise. AND operator is applied between title of the title, keywords and abstract for the most relevant search of article.

2.1.2 Subject Relevancy

Select the research study only if it accommodates our research settings designed by our classification structure. It must support the fitting reactions of our research addresses and ought to be appropriate to one of the predefined orders. Reject irrelevantly researches that don't have a spot with any of the predefined classifications.

2.1.3 Year Wise Filter

Selected Research work must be appropriated from 2016 to 2019 by embedding's channel an off year-wise determination in each database which will result in decrease by and large outcomes and aides in finishing the research article. Reject all the articles less our selection criteria set in year wise selection mechanism.

2.1.4 Research Publisher

Chosen research work must be distributed in one of the four eminent logical databases for example (IEEE Scientific Database, 2014), (Springer, 2014), (Elsevier, 2014) and (ACM, 2014).

2.1.5 Crucial-Effects

Picked research work must have crucial gainful outcomes. Remove the research work if its proposition doesn't have a huge commitment in Grey wolf optimization algorithm

2.1.6 Results-Oriented

Chosen research work must be results-arranged methods delivering an outcome, not a basic overview. Have a short look on the conclusion area of the chose article and check that that commitment of this article has significant worth in the field of optimization algorithms. Result confirmation must be done by an incredible review on the off chance that it doesn't so expel the work.

2.2 REJECTION CRITERIA

2.2.1 Repetition

All the research in a particular research setting can't be consolidated. Subsequently, reject the research if these are undefined in the given research setting and only a solitary of them is picked.

2.2.2 Title Based rejection

Chosen research work can be advocated by having a concise take a gander at the title of the research articles. It might require some mastery while making a decision about the article however it will give a productive outcome. The recommendation and extraordinary consequences of the research must be maintained by solid assurances and experimentation. Remove the work if its title isn't coordinating you're identified with the examination points.

2.2.3 Abstract based rejection

Sometimes, it's particularly difficult in choosing the research article by checking with the title of the article so right now should peruse the theoretical of the article from which you can get appropriate data in regards to the article.

3. LITERATURE STUDY

The grey wolf optimizer is a novel heuristic swarm intelligent optimization algorithm proposed by Seyedali Mirjalili et al. in 2014. It is considered as simple and easy to implement metaheuristic algorithms.

3.1 Working mechanism of GWO

This section are explain the GWO. How to GWO are work as fellow different part of working and mathematically step.

3.2 Inspiration of GWO

Grey Wolf Optimization is swarm intelligence technique. The grey wolves pack leadership and hunting are social intelligence of GWO. The social hierarchy of power and domination are related in each pack of grey wolves. The group leader is alpha. Alpha is power full wolf, which lead the whole pack in hunting, movement and feed. If alpha are died or old than the power full wolf in beta become alpha.

3.3 Hunt

A wolf is a move to any place around the prey. However, this social intelligence is not enough for grey wolves. During hunting the group hierarchy plays an important part during the hunting and the stability of a pack. To reproduce social ranking, the three finest solutions are Alpha, Beta, and Delta. Although in mature. The simplicity of GWO has only one solution to the class.

3.4 Mathematical step of Grey Wolf Optimization

This part is shown the mathematical step of the Grey wolf optimization algorithm.

3.5 Encircling prey

Mathematically step of Grey wolf optimization have two point in a dimensional space and update the new position based on others. The following calculation the recommended to reproduce this:

$$X(t+1) = X(t) - B.D \quad (1)$$

Where X (t +1) is the new position of the wolf, X (t) is the current position, B is a coefficient matrix and D is a vector that depends on the location of the prey (X_p) and is calculated as follows:

$$D = | C.\ X_p(t) - X(t) | \quad (2)$$

Where,

$$M = 2.r_2$$

Note that r_2 is a casually created vector from the interval [0, 1]. With these two equations, a solution is able to relocate around another solution. Note that the equations use vector, so this is applied to any number of dimension.

Note that the casual components in the beyond equation simulates various step sizes and movement speeds of grey wolves. The equation to define their values is as follows:

$$B = 2a.\ r_1 - a \quad (3)$$

Where is a vector where its value is linearly reduced from 2 to 0 during the run. r1 is a randomly produced vector from the interval [0, 1]. The equation to update the parameter is as follow:

$$a = 2 - t\left(\frac{2}{T}\right) \quad (4)$$

Where, t shown that the current iteration and T is the maximum number of epochs.

3.5 GWO Technique

The GWO architecture is one of the swarm intelligence algorithms, the optimization procedure with the solution of a random set, in every problem maintains with the help of vector and values of parameters. In every iteration, to get the objective values of each solution to calculate the first step. Therefore, all the time one variable save in objective. When solving the problem in GWO the vector and variable are mention and key data are save in memory, three vector and three variables, these vector and variable storage the location and principle values, the value of Alpha, Beta and Delta wolves in the memory. These variable are updated when updating the previous to position update procedure. The GWO architecture update the solution applies equation 5, 7. Now order the compute these equations, the space b/w the resent clarification and alpha, beta and delta would be calculated initial value apply equation 7. The involvement of alpha, beta, and delta to improve the position of the solution is then calculate applying equation 6. The objective value of the solution and their position, the main supervisory parameter of Grey Wolf Optimization (B, M and a) are updating earlier to position improving.

$$Z_1 = X_\alpha(t) - B_1 . D_\alpha$$

$$Z_2 = X_\beta(t) - B_2 . D_\beta \quad (6)$$

$$Z_3 = X_\delta(t) - B_3 . D_\delta$$

$D\alpha$, D_β and D_δ are calculate applying equation. 7

$$D\alpha = | M_1 . X_\alpha - Z |$$

$$D_\beta = | M_2 . X_\beta - Z | \quad (7)$$

$$D_\delta = | M_3 . X_\delta - Z |$$

3.6 Exploitation and exploration

Exploitation and Exploration are two opposing methods [2] which are the approaches that may present when optimization a provided issue. In the process consideration, the approach finds out the new solution of the issue search space by using unexpected variations of the solution since the fundamental goal is to find the promising field in the research landscape and avoiding solution from standstill in a local optimum. In manipulation, locally find the new solution like improve the estimated solution to achieve the exploitation process by find out the locality of each solution. Consequently continuing the variations in the solution would be completed to unite toward the global optimum. The actual target is that exploitation and exploration both are balance in search space then to get the accuracy in result. Consequently, architecture should be capable to addresses and balance in exploitation and exploration find out the optimization problem and accurate target of the global optimum. The key control parameter of Grey Wolf Optimization support the exploitation variable is M. Its parameter constantly given casual values of [0, 2]. The variations are in the involvement of the prey are describing the new position and this involvement is powerful when “M > 1; the solution descends and close to the prey. This parameter given a random value irrespective of iteration number, during the optimization investigation is stress in the case of local optima.
In addition, adjusting parameter that reasons exploration is B. This parameter value depends on a, and reduce to this value 2 to 0. The random value of the parameter, the range of the value is [-2, 2] for the parameter B. Exploration is onward after B> 1 or B < -1, while there is emphasize on exploitation when -1 < B < 1.
As above mention better balanced among exploitation and exploration to find out the exact search in global and local optimum using the algorithm. The GWO is balanced when reducing the corrector of the parameter in the equation for the parameter B.

3.7 GWO variants

GWO are applied to many field to get the good result and compare with other standard algorithm. In this paper I can discuss all type of GWO model like standard GWO, modified GWO and hybrid GWO. And also shown the result in table.

3.8 Standard Grey Wolf Optimization

GWO algorithm uses many fields to get a good result. GWO also use in the search patterns to find out the optimization problem like a smart grid power system. [3]. According to the literature review, GWO is proposed the societal behavior and hunting mechanism is proposed to clusters algorithm for VANETs and decree sing factor of grey wolf nature.[4]. The heat and strong communication is a significant optimization task in the power computing system for allocation generation and heat output to the committed units so using the GWO approach for the “CHPD problem. The efficiency of the introduced technique is validated by transporting out strongly tests on three various CHPD problem included as static economic dispatch environmental-economic dispatch and dynamic economic dispatch.[5]. GWO algorithm also uses the fuzzy control systems (CSS) with reducing the parametric sensitivity. Grey Wolf optimization algorithm solving the optimization problem, where the goal function includes the output awareness function. GWO motivation is based on its low-computational cost. The tuning method is validation in an experiment case study of the position managing for a laboratory nonlinear servo system and TSK PI-FCs with a reduce process small time constant sensitivity are offered. [6]. Grey wolf optimization algorithm inspired by the grey wolves and its behavior like leadership hierarchy and hunting mechanism. This method is noise-free. GWO result is compared with other optimization algorithms like a hybrid model of particle swarm optimization and gravitation search algorithm (PSOGSA) and genetic algorithm (GA). GWO performs a surface wave analysis that can present a better balanced in exploitation and exploration. GWO is very simple and few parameters to implemented and get a better result. [7]. Grey wolf also use to solve the Battery energy storage system sizing problem simultaneously. The solving this problem use different algorithms like Grey Wolf Optimization (GWO) produces the best optimal solutions compared to other like particle swarm optimization (PSO), artificial bee colony (ABC), gravitational search algorithm (GSA), and genetic algorithm (GA). [8]. Grey wolf optimization solves the optimal placement and sizing of the active power filter. Grey wolf optimization algorithm recognizes the optimal size of the active power filter and compares this result to other algorithms

like particle swarm optimization (PSO) and harmony search (HS). Grey wolf optimization gave a significant outcome and this outcome compared to other algorithms like particle swarm optimization and harmony search. [9]

3.9 Modified of Grey wolf Optimization

Due to the several real-world problem optimization problems, GWO has been reformed in search space of difficult domains. Some reforms are done to update the architecture since the GWO has few limitations in applications to real-world problems. In modification improve the operation of GWO. Further, improve varieties and reform version to improve the exploration and exploitation in GWO. Grey wolf optimization improve as multi-objective grey wolf optimization to solve the multi-objective optimization issue for the first time. This multi-objective grey wolf optimization result compare with other like multi-objective evolutionary algorithm based on decomposition and multi-objective particle swarm optimization and result shown that the multi0objective grey wolf optimization provides a better result as compare to other. [10]. Evolutionary population dynamic (EPD) removal the poor individual in nature. Evolutionary population dynamic also uses grey wolf optimization to remove the poor search agent in Grey wolf optimization and reposition them around “alpha, beta, or delta wolves to enhance exploitation [11]. The grey wolf optimization is a population-based algorithm. The Grey wolf optimization provides a better solution as compared to another optimization algorithm. Because Grey wolf optimization faces the problem, GWO still traps the local optima and this problem due to the insufficient diversity. So I improve the modified grey wolf optimization to solving both global and real-world optimization problems. The levy flight (LF) greedy selection strategies are integrated with the modified hunting phases. According to Levy distribution levy flight class of scale-free walk with randomly oriented step. Levy embedded to GWO (LGWO), it was compared to other optimizers. Experimental results and numerical tests show that the performance of LGWO is expressively better than GWO [12]. Find out the medical diagnosis with the help of improving grey wolf optimization and kernel extreme learning machine IGWO-KELM. IGWO discovery the optimal features subset for medical data. GA performs the diversified initial position and Grey wolf optimization (GWO) perform the current position to the new position of the population in the searching space, IGWO also compares with original GA and GWO. IGWO performance and accuracy is better than original GA and GWO” [13]. Grey wolf optimization has a two-part one part is exploitation and another part is exploration. If both are not balanced so you missed your target location. Enhanced Grey Wolf Optimization (EGWO) algorithms are proposed for the good hunting mechanism. Exploration and exploitation both are balanced in the EGWO algorithm. EGWO algorithm proposed better results as compared to other well-known algorithms [14]. In the grey wolf optimization not balanced in exploitation and exploration so enhanced grey wolf optimization improves the exploration and applied in analog circuit design. Enhanced grey wolf optimization applied to 23 different benchmark functions and compare with grey wolf optimization and Particle swarm optimization [15]. Improve grey wolf optimization (IGWO) integrates with modified augmented (MAL). Modified augmented deal with the constrained problem because modified augmented convert the constrained to the unconstrained problem and IGWO performs the unconstrained. This proposed modal tested for different well-known benchmark problems and also engineering applications. The result shows that the MAL-IGWO algorithm better performance to other approaches [16].

3.10 Hybrid Grey Wolf Optimization

GWO hybridized with another algorithm to get the hybrid model to improve the result. I discuss the different hybrid models and this hybrid model to apply the different optimization problems and get a better result. GWO hybrid with Genetic Algorithm. This hybrid algorithm is balanced between exploration and exploitation and reduce the population to the sub-population and using operation in search space algorithm to increase the diversity of sub-population. And applying the genetic algorithms in the whole population. HGWOGA compare with the other 8 benchmark algorithm. The result is faster than other comparative algorithms [17]. Most of the important technologies in the manufacturing industry are welding. To develop the hybrid model Multi-Objective Grey Wolf Optimization Algorithm (HMOGHO). This method applying in the manufacturing industry to solve different types of problems like three dynamic events namely, release delay, machine breakdown, a job with poor quality. This hybrid method to solve the multi-objective dynamic welding scheduling problem (MODWSP) [18]. Mean Grey Wolf Optimization (MGWO) hybrid with Whale Optimization Algorithm (WOA). This method targets the two things, firstly exploitation and exploration are a balance in Grey wolf optimization and secondly the entire population to refrain from the premature convergence rate and trapping in local minima. This hybrid model performance is very worthy because the convergence rate is very faster and also accuracy is better than other meta-heuristics. This hybrid algorithm resolves the maximum number of optimization problems in reality [19]. Biogeography-based optimization makes a hybrid algorithm with a Grey wolf optimization algorithm to balance exploitation and exploration. BBO and GWO introduce the new strategy, like a single-dimensional alternating strategy [20]. Grey wolf optimization also use in the medical field to find out the different types of diseases. Grey wolf optimization hybrid with supervised artificial neural network (ANN). This hybrid algorithm target the MRI classification accuracy by selecting the optimal parameter of ANN. This hybrid algorithm output compares with the neural networks (NN) [21]. Grey wolf optimization makes a hybrid model with particle swarm optimization to improve the global search and convergence performance. The actual target is that increase the performance of exploitation in particle swarm optimization and exploration improves in the grey wolf optimization [22]. Grey wolf optimization algorithm hybrid with crow search algorithm (CSA). This model call GWOCSA. And this model applied to the 23 benchmark function. The hybrid model performance is better than the stander model. This hybrid model solves feature selection. This model solves the real-world problem about the feature selection [23].

***Table 1**: Standard GWO to applied the different optimization problem and compared with other algorithm.*

Author	Perform	Comparison with
Belkacem Mahdad. 2015	Solving security smart grid power help of pattern search algo-rithm	BBO, DE, PSO, ABC
Muhammad Fahad.2017	Clustering algorithm for VANET's is proposed social behavior	Evolutionary programming, Genetic programming, Differential evolution
N.Jayakumar, 2015	Solving the heat and power dispatch	PSO, HS, LR and IACS
Radu Precup, 2017	Reduce the parameter sensitivity with fuzzy control system	PSO and GSA
Xianhai Song, 2015	Parameter estimate in surface waves	PSO, GA, and GSA
Shivashankar sukumar, 2018	Battery sizing problem	PSO, ABC, GA, and GSA
Ashokkumar lakum. 2019	To recognize the optimal size of active power filter	PSO and HS

***Table 2:** Modified Grey Wolf Optimization and applied to different optimization problem and their comparison.*

Authors	Perform	Comparison with
Seyedali Mirjalili 2016	Multi-Objective Grey Wolf Optimization applied 10 different benchmark	Multi-objective Evolutionary Algorithm
Shahrzad Saremi 2014	Improve the whole population with median fitness	Standard GWO
Ali Asghar Heidari 2017	Improve Grey wolf to Levy-embedded Grey wolf optimization	Standard Grey wolf optimization and optimization algorithm
Qiang Li 2017	Medical diagnosis problem	Genetic Algorithm and Grey Wolf Optimization
Hamani Joshi 2017	Balancing between exploitation and exploration	Well know algorithm
MA Mushahhid Majeed 2018	Sizing technique with improved accuracy	23 benchmark functions
Wen Long 2016	Convert a constrained problem into a an unconstrained	Test the 24 well-known benchmark

***Table 3**: Hybrid model of grey wolf optimization algorithm and its working and comparison.*

	Perform	Compare with
Mohammad A. Tawhid 2017	Improved exploitation exploration , dimensionality reduction and whole population refrain from the premature convergence	8 benchmark algorithm
Chao Lu, Liang Gao 2017	Improve the welding scheduling problem	NSGA-11, SPEA 2 and Multi-objective mete heuristics

Narinder Singh and Hanaa Hachimi 2018	Improved exploitation and exploration also refrain premature convergence	GWO, PSO, and WOA
Xinming Zhang 2018	Improved exploitation, exploration and multi-migration	BBO and GWO
Heba M. Ahmed	Improved the accuracy of magnetic resonance image	NN
Narinder singh 2017	Improve exploitation in PSO and exploration in GWO	Particle swarm optimization and grey wolf optimization
Sankalap Arora 2019	In balance exploitation and exploration	Compare with GWO, CSA and PSO

4. CONCLUSION AND FUTURE WORK

According to the paper review, the stander grey wolf optimization algorithm is not stable. Grey wolf optimization is not balanced in exploitation and exploration. The modified model of grey wolf optimization performance is better as compare to the stander model but hybrid model given the better optimization solution so according to different papers hybrid models are better but in hybrid models increase the complex city and time consumption. In future work need a better model they increase the performance of the grey wolf optimization algorithm and that model is less complex and a minimum of time consumption. GWO is hybrid with the Whale Optimization Algorithm to better performce in exploitation and exploration.

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