Comparative Analysis Of Nature-Inspired Meta-Heuristic Optimization Algorithms

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Abstract— **Metaheuristic methods were utilized to determine the most appropriate solution to complicated problems in engineering applications, telecommunications issues, security issues, etc. This research and development has become a prime concern in the ever-evolving age of technologies. Nowadays, many metaheuristic algorithms are gaining popularity, like "Genetic Algorithms (GA) and Particle Swarm Optimization (PSO)." This research provides an overview of the characteristics of a few metaheuristic optimization techniques. It contrasts "the Firefly Algorithm (FA), Artificial Bee Colony (ABC) Algorithm, Cuckoo Search (CS), and Whale Optimization Algorithm with the Particle Swarm Optimization (PSO) ".The purpose of this study is to assess and evaluate the publications from 2010 to 2023 using a number of variables, which include (a) The value of the reviewed studies based on the year of publication.(b) Studies comparing PSO to metaheuristic algorithms (c) Performance evaluation of comparative algorithms (d) Inspirational approaches and early proposed studies and years for metaheuristic algorithms and (e) Metaheuristic algorithms compared to PSO research. In-depth comparisons between PSO and the most widely used metaheuristic algorithms are made in this work.**

Keywords— *Particle swarm optimization (PSO), Metaheuristic algorithms, Heuristic algorithms Optimization algorithms, Swarm intelligence (SI).*

I. INTRODUCTION

An optimization problem is a computer problem that aims to find the optimal solution out of all possible solutions. In an optimization problem, the mathematical relationship between the objectives and constraints and the decision variables determines the complexity of the solution and the solutions or algorithms that can be used for optimization to find true solutions. A metaheuristic algorithm is a search procedure designed to find an optimal solution to a complex and ill-posed problem. The emergence of metaheuristic algorithms for solving such problems is one of the most successful in the field of research in the last two decades.

Metaheuristic algorithms fall into two broad categories: single-based algorithms and population-based algorithms. The main principle of a metaheuristic algorithm (also called a trajectory algorithm) is to generate a solution at each run[21]. The solution is to improve the use of the community mechanism. Unlike single-population metaheuristics, population-based metaheuristics generate a set of multiple solutions (populations) in each run. The four main categories of population metaheuristics comprise evolutionary, herd intelligence, events, and physics. The attention of the Researchers from World Wide was attracted by PSO declaring it as a fast and effective optimization technique. PSO draws inspiration from the motions of some social animals, primarily when they are completing crucial functions like foraging. PSO, an optimization technique introduced by Kennedy and Eberhart [44], was implemented for the first time in 1995 (Eberhart & Kennedy, 1995).

The given section focuses on one of the most popular metaheuristics. In this paper, we use metaheuristic methods based on artificial swimming skills to investigate how PSO compares with them. This article is divided into the following sections: Several studies carried out between 2010 and 2023 compared PSO with various metaheuristic techniques in the data analysis part. In the research part, findings from clinical studies are evaluated from the overview. The final section provides a summary of the evaluation results.

II. LITERATURE SURVEY

Several research investigations have been examined in this review of the literature, and selective metaheuristic approaches are contrasted with particle swarm optimization (PSO) in earlier studies. PSO is a swarm intelligence-inspired population metaheuristic algorithm. The effectiveness of PSO and various metaheuristic algorithms in various optimization problems has been compared in numerous researches. Kulkarni and Desai [4] review ABC and PSO algorithm performance in multi-dimensional optimization of fundamental measurement functions in this study [4]. During their experimental work, they found that the ABC &PSO performed similarly for unimodal functions. Rather, we can show that the ABC algorithm excels the PSO method in terms of solution quality for multimodal functions. The 2011 paper that Civicioglu and Besdok proposed [16] They examined the CS, PSO, DE, and ABC algorithms' conceptual underpinnings. By analyzing the data, they came to the conclusion (to paraphrase or not to paraphrase) that evaluating the data was successful. The DE method performs better than the ABC algorithm, whereas the CS and PSO algorithms perform similarly.

Both ABC and PSO are used to solve the problem of protein structure prediction. Alqattan, Z. N. M. and Abdullah, R. in 2013[1] investigated the performance of two algorithms when using an experimental short sequence protein called Met-enkaflin for 3D structure prediction. Finally, they clearly show the power of PSO search strategy, and Time, Avg .NFE & rate of success are, respectively, 70%, 73%, and 3.6% higher than ABC. Additionally, they assert that at Std.dev values, ABC results are 74% more reliable than PSO results[26]. In some cases, PSO has shown better performance compared to FA. For example, in a study by Bhushan, B., & Pillai, S. S. in 2013, PSO outperformed FA in performance analysis in most of the non-linear benchmark functions. Similarly, in a study by Marie-Sainte, SouadLarabi, Saba, Tanzila, Alotaibi, and Sihaam (2019), the Firefly Algorithm and PSO to find the values that is optimal for Linear Regression (LR) coefficients[30].

In other cases, FA has shown better performance compared to PSO. For example, in a study by Siabal K. Pal, C.S Rai, and Amrit Pal Singh in (2012), FA seems to do well for high noise in noisy linear optimization problems. Similarly, in a study by Chatterjee, A., Mahanti, G. K., & Chatterjee, A. in (2012), the comparative performance of FA and PSO clearly shows that FA is superior to PSO in terms of finding the optimal solution for the desired beam pattern.

TABLE I. THE VALUE OF STUDIES REVIEWED BASED ON PUBLICATION YEAR.

Publication Year [References]	No. of Publication
Several studies were conducted in 2010 by researchers such as Selvi and Umarani[31], Unler and Murat[32], Yang (in two separate papers)[6][7], Calçada and colleagues, Hammouche and team, Bashiri and Karimi[5], and Hoang and co.	8
2011[Changyin Sun, Haina Zhao,Yifan Wang in 2011, Kavitha Sooda, T. R. Gopalakrishnan Nair in 2011]	2
2012[Diao and Shen in 2012 [36], Bharati & Gholizadehin in 2012, Mansour & Kawanin 2012 [45], Mishra and co. in 2012 [46], Pal and co. in 2012, Ramos and co. in 2012 [47]]	8
2013[Adnan and Razzaque in 2013 [15], Bharat Bhushan; Sarath S. Pillai in 2013 [48], Yuanwen Yang; Yi Mao; Peng Yang; Yuanmeng Jiang in 2013, Siddharth Agarwal; Amrit Pal Singh; Nitin Anand in 2013, G. Giftson Samuel; C. Christober Asir Rajan in 2013 [49]]	6
In 2014[Azadeh and co. in 2014, Adrian and co. in 2014 [19]]	2
In 2015 [Garca-Nieto and co., 2015; Hussain and co., 2015 [23] ; Li and co., 2015; Nayak and co. in 2015 [50]; Nguyen and Truong, in 2015; Wahab and co. in 2015 [51]; Asghari and Navimipour in 2015]	6
In 2016, several studies were published [Das and co. (2016), Gavrilas in 2016, Kulkarni and Desai in 2016[4], Kuo and co. in 2016, Ozcan in 2016 [41], and Sangwan and co. in 2016]	6
2017 [Ramadan and co. in 2017, Ülker in 2017 [37], Jia and Lichti in 2017, Medani and co. in 2017 [10], Rezk and co. in 2017, Babak Dizangian & Ali Hooshyari in 2017 [29]]	5
2018[Lim and Leong in 2018, Sukumar and co. in 2018 [17], Rahaman and Kule in 2018]	3
2019[Ahmidand co. in 2019 [20], Yusup and co.in 2019, Izadi & Sheijani in 2019, Yaghoubi & Akrami in 2019, Ahmidand co. in 2019, Padma and Shiferaw in 2019, and Mirjalili and co.in 2014 [39]]	8
In 2020, several studies were published that are Hussein and Mousa [23], Mohamed and Abdelsalam, and Adetunji and co. in 2020 [43]	3
2021 [Xu, L., Song, B., & Cao, M. in 2021[3],Alaa Tharwat,Wolfram Schenck in 2021 [18] , Abraham Ayeba Alfa, Sanjay Misra in 2021]	3
2022 [Tareq M. Shami, Ayaman A. El-Saleh in 2022, Ahmed S. Menesy, I. O. Habiballah & Hamdy M. Sultan 2022 [28]]	2
2023[Jaun Haung in 2023,Ch. Amarendra, A. Pandian in 2023, Abubakr S. Issa; Yossra H. Ali in 2023 [27]]	3

Using the whale optimization algorithm (WOA) for the optimal reactive power dispatch (ORPD) problem, Medani and co. proposed the study [11] (Medani, Sayah, &Bekrar, 2017). With PSO, PSO with variable acceleration coefficient ,& a few other methods, they compared the outcome. They ended up deciding that the WOA algorithm is quite impactful in quick convergence to the global optimum based on the findings they had obtained. Musaviradand co. [12] They take several population-based heuristic algorithms to do the index, and these algorithms are WOA, CS, FA, BA, DE, PSO, GA, GWO, COA, Imperialistic Competitive Algorithm (ICA), and Biogeography-Based Optimization (BBO), Training- in Quantitative Research Area (Mousavirad, Schaefer, & Ebrahimpour-Komleh, 2019) [12] for optimization based on image learning (TLBO) and gravity search algorithm (GSA). As a result, it is clear that ICA performs better than other algorithms.

In this paper [10], the authors suggest two fundamental algorithms, PSO and WOA, for measuring and placing distributed generation (DG) units optimally in study of network planning (Adetunji, Hofsajer, & Cheng, 2020). In their study, PSO & WOA explain the benefits and drawbacks of each approach for reaching the ideal size of DG units in the transmission network. In a paper proposed by A. S. Menesy, I. O. Habiballah and H. M. Sultan (2022), PSO and WOA optimization methods are used to solve the optimal power flow problem. The objective function was tested on a 30-bus IEEE network. Based on the simulation results, the proposed WOA method has the best performance compared to the conventional technique called PSO.

Babak Dizangian& Ali Hooshyari in 2017 [29] evaluated and compared the performance of few algorithms which included PSO, WOA and CS Algorithm in optimization of unconstrained problems. After comparing the optimization results, it was observed that PSO showed better performance compared to other algorithms. WOA & CS Algorithm showed a bad performance as they could not converge to good solutions with an acceptable number of iterations. Jinjin Ding, Kunjin Wang, Qian Zhang, Qiubo Ye, and Yuan Ma proposed a paper [13] [33] on Partial Swarm Optimization-Cocoa Search Algorithm (PSO-CS) capable of solving complex linear optimization problems. It combines the iterative scheme of PSO and Cuckoo Search algorithm.

The Cuckoo search technique is used by Yang and Deb to resolve engineering optimization issues in 2010 [14]. The

outcomes of the study demonstrate that the CS algorithm is superior to the PSO.

Yang and co.[25] compared the benefits and drawbacks of Metaheuristic algorithms and gradient-based methods (FF, PSO, ACO, BCO, BA, CS, etc.) that were inspired by nature (Yang, Deb, Fong, He, & Zhao, 2016). Rezk and co. compare the effectiveness of CS & PSO to extract the partially shadowed photovoltaic system's global peak power point. The results show that the CS & PSO based trackers, when compared to traditional algorithms, have great accuracy and stability in extracting the global MPP regardless of the global MPP. The PSO method was employed by Hussain and co. to address concerns with software clustering [24] (Hussain, Khanum, Abbasi, &Javed, 2015). Three distinct software testing platforms were used to examine the PSO approach, and the outcomes were compared with GA. The simulation results demonstrated that, in comparison to GA, the PSO technique had a quick convergence. It was also noted that additional research was needed to determine the appropriate PSO parameter values.

PSO and CS algorithms were compared in a study by Adnan and Razzaque in 2013[15]. This algorithm is applied to the specific distance function of the problem. In this study, it is claimed that the CS algorithm is as effective as the PSO algorithm to find the global optimal solution. Abubar S. Issa, Yossra H. Ali and Tarik A. Rashid compared swarm methods for the categorization of COVID-19 on X-ray in this 2023 study[35] . The goal of the study was to determine the best swarm algorithm for precisely detecting COVID-19 on X-ray picture. The accuracy, sensitivity, and specificity of various swarm algorithm were investigated , compared and reviewed by the researchers. The study's conclusions shed light on the possible application of swarm algorithms for the early identification of COVID-19.

TABLE II. STUDIES COMPARING PSO TO METAHEURISTIC ALGORITHMS

Algorithm	Studies
Algorithm for artificial bee colonies (ABC)	Yang in 2010a[6], Martins, L. F. B. , Gamino in 2016 [2], Kulkarni and Desai[6], Alqattan Z. N. M., & Abdullah, R. in 2013 [1], Civicioglu and Besdok in 2011[16] and Sukumar et al in 2018
Firefly algorithm (FA)	Saibal K. Pal, C.S Rai, and Amrit Pal Singh in 2012, Chatterjee, A., Mahanti, G. K., & Chatterjee, A. in 2012, Bharat Bhushan and Sarath S. Pillai in 2013, Marie-Sainte, SouadLarabi, Saba, Tanzila, Alotaibi, and Sihaam in 2019
Whale Optimization (WOA) Algorithm	Adetunji and co., and Medaniand co. in 2017 [43], Babak Dizangian & Ali Hooshyari in 2017 [29], Mousavirad and co. in 2019, Ahmed S. Menesy, I. O. Habiballah & Hamdy [28] , M. Sultan in 2022
(CS)Cuckoo search	Yang & Deb in 2010 [9], Besdok & Civicioglui n 2011 [16], Kawam & Mansour in 2012, Adnan & Razzaque in 2013, Kumar and Rawat in 2015, Nguyen and Troung in 2015, Rezk and co. in 2017, Mousarvirad and co. in 2019[12]

III. COMPARATIVE STUDY

This section presents a survey of research conducted between 2010 and 2023 comparing PSO and other metaheuristic algorithms. These studies are then reviewed based on the year of publication, research value, performance evaluation of compared algorithms, heuristic algorithms compared to PSO, inspiring approaches and early proposals, and early proposals and years.

As we will see Table I. shows The value of studies reviewed based on the year of publication. We can observe from the table that 2010, 2012, 2016 and 2019 are the strongest research years in comparing PSO with other metaheuristic algorithms[42].

In Table II, this section shows review of the various paper in which several metaheuristic algorithm compared with the PSO algorithm [27]. The Artificial Bee colony Algorithm is the most utilized PSO algorithm in the literature.

TABLE III. RESULTS OF COMPARED ALGORITHMS' PERFORMANCE

Algorithm Compared	References	Which one performs better, according to the study?
PSO Vs ABC	Kulkarni & Desai in 2016 [4]	ABC
PSO Vs ABC	Yang (2010a)[6]	The ABC algorithm - high accuracy results, PSO algorithm- optimal results in a shorter time
PSO Vs ABC	Fortes, E. de V., de Araujo, P. B., Martins[2], L. F. B., and Miotto, E. L. in 2016	ABC
PSO Vs FA	Saibal K. Pal, C.S Rai, and Amrit Pal Singh in 2012	FA
PSO Vs FA	Marie-Sainte, SouadLarabi, Saba, Tanzila, Alotaibi, and Sihaam in 2019	PSO
PSO Vs FA	Chatterjee, A., Mahanti, G. K., & Chatterjee, A. in (2012)	FA
PSO Vs WOA	Medani and co. in 2017 [11]	WOA
CS, FA, BA, DE, GA, GWO, GWO Vs. PSO; WOA Vs. PSO, ICA, BBO, TLBO, and GSA	Mousavirad and co. in 2019 [12]	ICA
PSO vs. WOA	Adetunji and co. in 2020 [43]	For many measures for power system networks, both methods outperform one another.
PSO vs WOA	A. S. Menesy, I. O. Habiballah & H. M. Sultan in 2022 [28]	WOA
PSO vs WCA, WOA, CS	Babak Dizangian & Ali Hooshyari [29]	WCA followed by PSO
PSO vs CS	Rezk and co. in 2017	CS
PSO vs CS	Razzaque & Adnan in 2013 [2]	When using PSO to identify the genuine global optimum, CS and

		PSO perform equally well, however PSO performs better computationally than CS.
PSO vs CS	Nguyen and Truong [41]	CS

The following Table III. gives the review about the evaluated performance of compared algorithm . It simple shows which algorithm perform better as compared to other when tested with some parameter. The table illustrates that the ABC algorithm excels PSO and other metaheuristic algorithms. In some of the analyses research, the PSO method usually produces improved result than other algorithms.

TABLE IV.   METAHEURISTIC ALGORITHMS, WITH THEIR PIONEERING METHODS, EARLY SUGGESTED RESEARCH, AND YEARS.

Algorithm	Inspiration	Study	Year
ABC	Honeybee	Karaboga and Basturk in 2006 [40]	2006
CS	Cuckoo Bird	Deb and Yang [9]	2009
FA	Firefly	Yang in 2010c [8]	2010
WOA	Humpback Whales	Mirjalili and Lewis in 2016 [39]	2016

Table IV. shows Metaheuristic algorithms, with their pioneering methods, early suggested research, and years. Table V shows Studies comparing PSO to metaheuristic algorithms

TABLE V.   STUDIES COMPARING PSO TO METAHEURISTIC ALGORITHMS

Application area	References
Multilevel thresholding problem	Mousavirad and co. in 2019 [12], Hammouche and co. in 2010 [34]
Prediction Techniques	Marie-Sainte, SouadLarabi, Saba, Tanzila, Alotaibi, and Sihaamin 2019 ,ReirestremosCutad , Bobby D in 2019.
Noisy non-linear optimization problem	Dervis Karaboga, Bahriye Akay in 2009,Huanzh eLi ,KunqiLiu & Xia Li in 2010[,Saibal K. Pal, C.S Rai, and Amrit Pal Singh in 2012
Reconfigurable antenna arrays	A. Chatterjee, G. K. Mahanti, and Arindam Chatterjee in 2012
Optimization in engineering and mathematics problems	Yang in 2010 [6], Yand and Deb, Li and co. in 2012 , Ulker in 2020 [37] , Sibalija in 2020 [38], Kule & Rahamanin in 2018 ,Asghari & Navimipour in 2015 [22], Kulkarni & Desai in 2016 [4]

IV. CONCLUSION

After the This paper is the study on comparison of PSO algorithm and some other metaheuristic algorithm. For this review study we have taken year from 2010 to 2023. We compared the four metaheuristic algorithm that are FA algorithm, Whale Optimization Algorithm, Cuckoo Search and Artificial Bee colony algorithm with the most popular PSO algorithm. We have study various parameter that are already explained in the above tables. By observing the Table 1, 2, 3 and 4 we come to an conclusion that PSO algorithm have greater impact in several application field. And also, PSO has performed great when compared to other algorithm in various parameters. This study is going to be very helpful for the other researchers who have interest in this topic. When PSO combined with the other method they provide better result for solving the optimization problem.

This study also provides the insights into the strengths and weaknesses of different optimization algorithms. It can help identify the most effective algorithm for solving a particular problem and provide guidance for researchers and practitioners to select the appropriate algorithm for their application.

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