Review Article

Bibliometric Survey on Particle Swarm Optimization Algorithms (2001–2021)

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Particle swarm optimization algorithms (PSOA) is a metaheuristic algorithm used to optimize computational problems using candidate solutions or particles based on selected quality measures. Despite the extensive research published, studies that critically examine its recent scientific developments and research impact are lacking. Therefore, the publication trends and research landscape on PSOA research were examined. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and bibliometric analysis techniques were applied to identify and analyze the published documents indexed in Scopus from 2001 to 2021. The published documents on PSOA increased from 8 to 1,717 (21,362.50%) due to the growing applications of PSOA in solving computational problems. "Conference papers" is the most common document type, whereas the most prolific researcher on PSOA is Andries P. Engelbrecht (South Africa). The most active affiliation (Ministry of Education) and funding organization (National Natural Science Foundation) are based in China. The research landscape on PSOA revealed high levels of publications, citations, and collaborations among the top authors, institutions, and countries worldwide. Keywords co-occurrence analysis revealed that "particle swarm optimization (PSO)" occurred more frequently than others. The findings of the study could provide researchers and policymakers with insights into the prospects and challenges of PSOA research relative to similar algorithms in the literature.

1. Introduction

Particle swarm optimization (PSO) is a metaheuristic approach that is typically applied to optimize or solve computational problems through the repetitive improvement of one or more candidate solutions based on the selected quality measures. According to [1], PSO can be defined as a population-based algorithm used for elucidating the optimal solution to computational problems. The concept of PSO was pioneered by Eberhart and Kennedy [2] as an approach for simulating and optimizing the social or swarm behavior of animals such as birds and fish schooling in nature. The algorithm operates in a cycleway and finds the resolution. In order to search for the globally optimal solution, each particle adjusts its forward direction based on its own best previous position and the current best position of all other particles [3]. In practice, the approach involves the movement of the position and velocity of candidate solutions (also termed particles) around the selected search space based on a numerical equation (4). It is generally assumed that the movement of the particle is primarily impacted by the local best-known position in the search space [5]. According to [5], the behavior of each particle is based on the combination of the individual and collective intelligence of the swarm population. Furthermore, each swarm particle represents the probable solution to the problem at hand. The study [1] reported that PSO is primed through the use of groups of randomly positioned particles so that consequently seek out an optimal point based on the N decision parameters of the optimization problem, as well as the position and velocity of each particle in the swarm. The particle

(candidate solution) of a PSO operation is characterized by its velocity (v_i) and position (x_i) [6]. The v_i and x_i can be updated based on the equation:

$$v_i^{t+1} = V_i^t + \alpha\varepsilon_i[g^* - x_i^t] + \beta\varepsilon_2[x_i^* - x_i^t]. \tag{1}$$

The term g^* represents the current or individual best solution for the particle i. Next, ε_1 and ε_2 are two arbitrary variables drawn from the uniform distribution in [0,1]. Furthermore, the terms α and β are variables for the learning process. Due to the constant movement, the position of each particle can be determined by the equation:

$$x_i^{t+1} = x_i^t + v_i^{t+1}. \tag{2}$$

However, it is essential to state that there are numerous versions of equations (1) and (2), which can be used to describe the conventional PSO algorithm, although the inertia function appears to be the most visible development in the field of study. Furthermore, the location of each swarm particle is determined by its velocity as well as the differences between its current and best position around its neighbors. Over time, the swarm model is strategically iterated to emphasize the search space area containing high-quality solutions [5].

Over the years, the PSO algorithm has been applied in academic, industrial, and policy research to solve nonlinear problems of social, economic, environmental, and technological dimensions around the world. This is mainly due to the numerous advantages of the algorithm, which include its low computational costs, higher performance, and minimal variable parameters when compared to other optimization algorithms used worldwide [1]. The approach is also considered an efficient, robust, and simple algorithm for carrying out optimization and solving numerical problems [7]. In addition, the heuristics-based swarm intelligence approach of PSOA provides an efficient alternative to analytic methods since it does not experience slow convergence or dimensionality problems, thus enhancing large-scale applications [8, 9]. Another advantage of PSOA is that it does not require the use of evolution operators such as crossover and mutation [10]. Lastly, [11] reported that PSO is highly applicable due to its flexibility and simplicity, which allows it to perform operations with limited variables.

Furthermore, PSOA is extensively applied for predicting many known systems. For example [12], employed the practical generator constraints in PSOA to investigate problems of economic dispatch (ED) in power systems. A separate study [13] used PSOA to optimally design and develop the proportional-integral-derivative (PID) controller of an AVR system. The findings showed that the proposed method is easy to implement and characterized by stable convergence and effective computational efficiency [14]. It demonstrated the potential of applying PSOA in the field of electromagnetics and engineering optimizations. Vesterstrøm and Thomsen [15] showed the potential of solving numerical benchmark problems using PSOA and evolutionary algorithms (EAs). Del Valle et al. [8] showed that the concept of PSOA can be applied in various areas of power systems to address nonlinear optimization problems.

Wang et al. [10] examined the application of PSOA in predicting the geometrical structure of crystals, which shows the applicability of the concept to basic chemistry and materials science research. The study employed the global minimization of free-energy surfaces merged with total-energy calculations in PSO to determine the structure of crystals. The findings showed that the approach is cost-effective and computationally efficient, which significantly reduced the optimization and search space variables and the convergence of the structure. Ma et al. [11] and Masoomi et al. [16] applied the PSO algorithm (PSOA) to critically analyze and solve (geographic information system) GIS-based land-use allocation problems. The studies observed that the combination of swarming intelligence-based optimization techniques into GIS presents opportunities to improve spatial diagnostic competencies. The technique involves the theory of a simple self-organized system of agents collaborating to address any challenge.

Further reviews of the scientific literature published on PSOA and indexed in the world's largest database (Elsevier Scopus) showed that 87,405 documents exist from 1960 to date. The search was based on the search query (("particle swarm" AND "optimi $*$ ation" OR "algorithm")) using the TITLE-ABS-KEY criteria. The distribution of published documents comprises Article (50,132); Conference Paper (34,033); Conference Review (1,331); Book Chapter (1,143); Review (458); Retracted (73); Erratum (65); Book (64); Editorial (30); Note (24); Letter (18); Data Paper (5); Short Survey (5); Undefined (24). The data indicate that PSOA research has gained significant interest over the years. Despite the numerous review papers along with other numerous document types on the field, studies that critically analyze the recent scientific developments and research impact of the field are lacking in the scientific literature.

Hence, the objective of the study is to critically examine the general publication trends, research landscape, and scientific advancements in Particle Swarm Optimization Algorithms. It is envisaged that the findings of the study will avail researchers in academia, industry, and policymaking sectors with valuable insights into the concepts, processes, prospects, and challenges of the PSOA when compared to other algorithms in the literature.

2. Methodology

In this study, the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was used to identify, screen, and analyze the published documents on Particle Swarm Optimization Algorithms indexed in the Elsevier Scopus database from 2001 to 2021. First, an appropriate search query was designed based on the title keywords ("particle swarm" AND "optimi $*$ ation" OR "algorithm") and executed in the Scopus database to identify all the published documents on the topic. The detailed search query used is as follows: TITLE ("particle swarm" AND "optimi $*$ ation" OR "algorithm") AND PUBYEAR >2000 AND PUBYEAR <2022 AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ch") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO

(LANGUAGE, "English")) AND (EXCLUDE (LANGUAGE, "Japanese") OR EXCLUDE (LANGUAGE, "Polish") OR EXCLUDE (LANGUAGE, "Spanish") OR EXCLUDE (LANGUAGE, "Chinese")) AND (EXCLUDE (LANGUAGE, "Croatian") OR EXCLUDE (LANGUAGE, "Portuguese") OR EXCLUDE (LANGUAGE, "French") OR EXCLUDE (LANGUAGE, "German")) AND (EXCLUDE (LANGUAGE, "Korean") OR EXCLUDE (LANGUAGE, "Russian") OR EXCLUDE (LANGUAGE, "Slovenian") OR EXCLUDE (LANGUAGE, "Turkish")). On completion, the related documents on the topic were recovered and subsequently analysed to examine the publication trends on the topic in the literature. Based on the TITLE criteria, the search query identified 22,974 published documents (or 1094 publications on average) during the timespan examined in the study. Figure 1 shows the flowchart of the study methodology used for identifying, screening, and analyzing the published documents on PSOA. Next, the analysis of the recovered documents was carried out in Microsoft Excel (version 2016) to examine the publication trends, major stakeholders (authors, institutions, funding bodies, and countries) as well as the top cited published documents on PSOA research in the literature.

Lastly, the bibliometric analysis of PSOA research was performed to examine the research landscape and scientific developments in PSOA research using the software VOSviewer (Version 1.16.17). For this analysis, the publications data on PSOA was recovered in CSV (comma-separated values) and RIS (Research Information Systems) formats from Scopus based on the selected timespan. Next, the CSV file was imputed in VOSviewer to analyze the research landscape on the topic using the co-authorship, keywords occurrence, and citations analysis feature on the software. Each analysis, the minimum number (n) of authors, keywords, and citations per published document was selected and analyzed in the VOSviewer software to examine the network visualization and relationship maps between the variables.

3. Results and Discussion

3.1. General Publication Trends. Figure 2 presents the general publication trends on PSOA research deduced from the Scopus database from 2001 to 2021. As observed, the number of published documents on the topic showed an incremental trajectory from 8 in 2001 to 1,717 in 2021 (i.e., 21,362.50% rise), although the highest publications count of 1,802 was recorded in 2019.

The most significant increase in publication rate was observed between 2005 and 2010, where the number of publications increased from 304 to 1,517, indicating a 399.013% increase over time. Intrinsically, it could be sensibly supposed that PSOA research has gained significant traction among researchers in the field. The growth in scientific interest in the field could attribute to the global trend in the application of stochastic techniques such as PSO in solving optimization problems. For example, the PSO has been applied in power systems for minimisation of fuel costs, loss power, voltage profile, and stability enhancement [17]. Further analysis revealed that the published documents on PSOA research are primarily comprised of conference papers (11,608), articles (10,994), book chapters (279), and review papers (93), as shown in Figure 3.

As observed, the researchers in the field of PSOA typically publish their findings in conference proceedings, as opposed to articles which is the norm in other fields. The preference for conference proceedings indicates that the rate of growth and development of ideas in the field is rapid. As such, experts in the field often elect to present the findings to their peers at conferences for quick dissemination, debates, and discussions, which typically helps early-career professionals, in particular, to obtain rapid feedback and build networks. The findings of the study also showed that a large number of review papers and articles had been published on the topic in the literature.

Reviews are peer-reviewed papers that provide researchers with detailed information about technological growth and scientific developments in any field. However, the preference for articles is mainly due to the long-established tradition of publishing in peer-reviewed journals, which in current times has become the basis for career advancement, academic prestige, and scientific awards among academics. The prestige and reputation of journals have become an important consideration not only for academics or scientific publishing but also for measuring the research impact of any field. Therefore, the top sources for published documents on PSOA research are shown in Figure 4.

As seen in Figure 4, the top source of publications on the topic are Lecture Notes in Computer Science Including Subseries, Lecture Notes in Artificial Intelligence, and Lecture Notes in Bioinformatics which accounts for 964 published documents or 4.20% of the total publications (TP) on PSOA research over the last 20 years. This is closely followed by Advances in Intelligent Systems and Computing (277 or 1.21% of TP), Applied Soft Computing (266 or 1.16%), Applied Mechanics and Materials (251 or 1.09%), and Advanced Materials Research (234 or 1.02%). The findings indicate that 4 out of the 5 publication sources on PSOA research are conference-based book series, except for Applied Soft Computing (ASC), which is a journal publication published by one of the world's largest publishers, Elsevier BV, Netherlands. According to the year 2020 data from the Scopus database, the ASC journal has a Citescore of 11.2, SCImago Journal Rank (SJR = 1.290), and Source Normalized Impact per Paper (SNIP = 2.472). The data shows that ASC is a high-impact journal publication, which informs the decision by researchers to publish their works.

3.2. Major Research Stakeholders. The research landscape and scientific developments in any field can be examined by analyzing the major research stakeholders. This consists of the various researchers, affiliations, organizations, and countries actively participating in any research field. Therefore, the major researchers actively working in the field are shown in Figure 5.
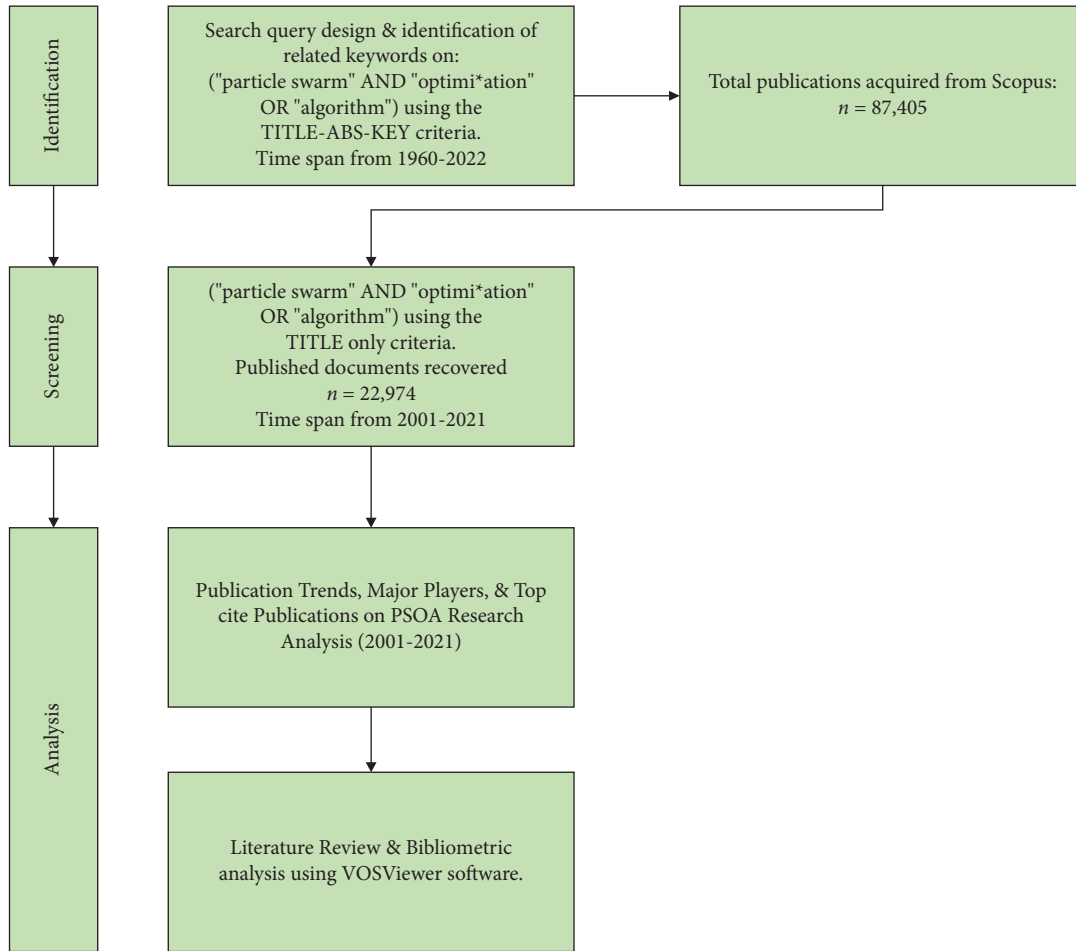
Figure 1: Process schematic for identification, screening, and analysis of published documents on PSOA research from scopus database.
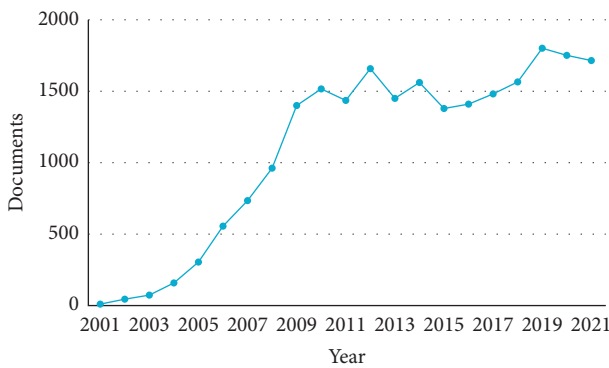

Figure 2: General publication trends on PSOA research (2001–2021).
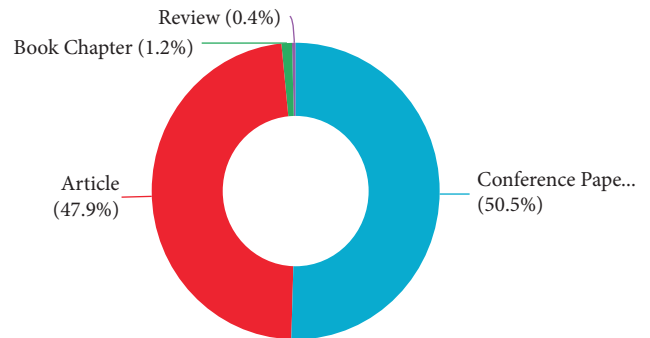

Figure 3: Distribution of document types for PSOA research publications (2001–2021).

The most prolific researcher on the topic is Andries P. Engelbrecht, with 98 publications or 0.43% of the TP. Other notable researchers in the field are Mengjie Zhang, Durbadal Mandal, Wenbo Xu, and Jun Sun with 80 (0.35%), 74 (0.32%), 74 (0.32%), and 73 (0.32%) published documents and (%TP), respectively. Further analysis revealed that the top researcher A.P. Engelbrecht is based at the Stellenbosch University in South Africa, whereas the others are based at other institutions such as Victoria University of Wellington, New Zealand (Mengjie Zhang); National Institute of Technology, India (Durbadal Mandal); Lanzhou Jiaotong University, China (Wenbo Xu); and Tianjin University of Science and Technology, China (Jun Sun). Overall, the findings indicate that the top 5 researchers in the field account for 1.74% (399 publications) of the TP (22,974 publications), which confirms their high rate of scholarly output over the last 20 years.
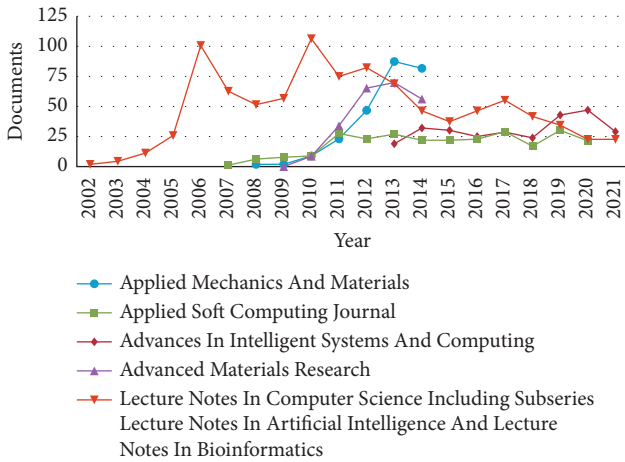
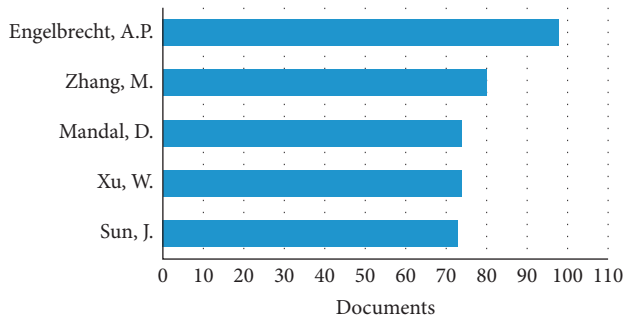FIGURE 4: Top journal sources for publications in PSOA research (2001–2021).

FIGURE 5: Top researchers on PSOA research (2001–2021).

FIGURE 6: Research output of top institutions on PSOA research (2001–2021).
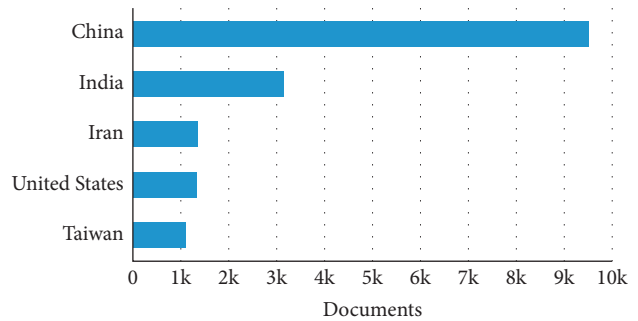
FIGURE 7: Top countries on PSOA research (2001–2021).

The high productivity of the researchers in the field could be attributed to numerous factors. Notably, the availability of financial support which typically exists as research grants, publication incentives, and monetary awards, is critical to the growth and development of any research field. Furthermore, the availability of top-of-the-range research facilities particularly in the area of STEM (science, technology, engineering, and mathematics), reportedly enhances the research output of scientists across the globe. The role of institutions in fostering academic research and scientific development is also critical to the growth of any field of research, which ultimately enhances the quantity and quality of publications as well as the international rankings of such institutions. Therefore, the impact of institutions on the research growth and scientific development of the PSOA field, as well as the publication output on the topic over the years, was examined, as shown in Figure 6.

The top 5 affiliations on the topic have each published over 200 publications during the timeframe examined in the paper. Similarly, it can be observed that 4 out of the top 5 institutions on PSOA research are based in the People's Republic of China. The outlier is Universiti Teknologi Malaysia, based in Malaysia. Next, the research activity of other nations other than China and Malaysia was examined, as shown in Figure 7.

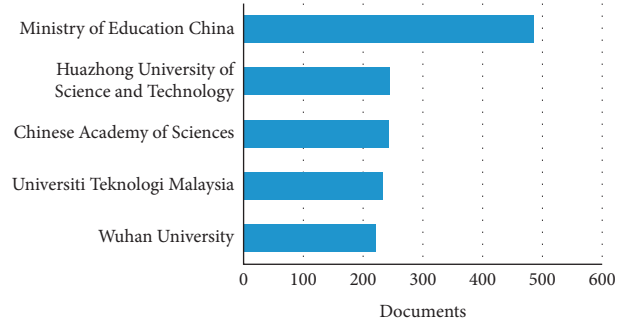The findings revealed that the top countries with active researchers and affiliations in PSOA research are China, India, Iran, the United States, and Taiwan. As observed, the top nations have all published over 1,000 publications during the timeframe examined in the study. The presence of China on the list can be attributed to the works of Wenbo Xu and Jun Sun, whereas the high productivity rate of Durbadal Mandal has placed India in the top 5 countries on PSOA research. However, the presence of Iran, the United States, and Taiwan could be attributed to the multiple works of numerous researchers and affiliations in their respective countries. This view is corroborated by the absence of South Africa, who, despite the works of Andries P. Engelbrecht of Stellenbosch University, does not feature in the top 5 countries.

3.3. Top Funding Organisations. The availability of financial support provided by various funding organizations, charities, nongovernmental organizations (NGOs) as well as government-based agencies plays a significant role in the growth and development of any research area. In this study, the role of financial support was examined using the data on research publications sponsored by funding bodies around the world. Figure 8 shows the top 5 organizations that have provided financial support or research funding for academics, researchers, and scientists in various affiliations and countries around the world.

As observed, the top 5 funding organizations for PSOA research are all based in the People's Republic of China (PRC). Furthermore, the findings indicate that the organizations have each funded over 180 publications in various mediums over the years. The top funder of PSOA research is
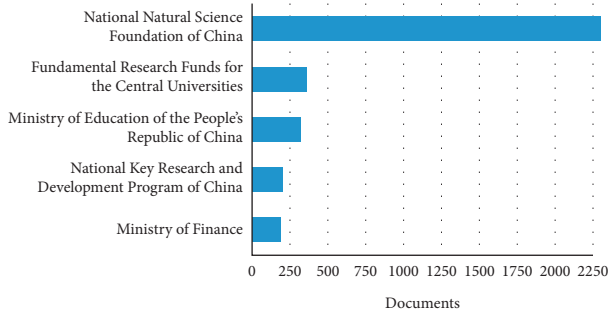
FIGURE 8: Top funding organizations sponsoring PSOA research.

the National Natural Science Foundation (NSFC) of China, with 2303 publications or 10.11% of the total publications (TP) on the topic. The dominance of the NSFC is closely followed by the Fundamental Research Funds for the Central Universities with 356 published documents or 1.55% of TP, and the Ministry of Education with 322 or 1.40% of TP. Other major funders are the National Key Research and Development Program (China), Ministry of Finance (China), Ministry of Science and Technology (Taiwan), *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) (Brazil), Ministry of Higher Education (Malaysia), National Research Foundation (Korea), Engineering and Physical Sciences Research Council (United Kingdom), and the European Commission (EC). The data shows that financial support or research funding for PSOA research is widely available, accessible, and distributed across the world. Hence, numerous academics, researchers, and scientists in various affiliations and countries around the world have had support over the years.

3.4. Top Cited Publications.
The analysis of the top-cited publications on PSOA Research was also examined in this study to elucidate their research impact on the topic in the literature. Table 1 presents an overview of the top 10 most cited publications on the topic based on the screening of publications with over 1000 citations during the period under examination.

As observed, the top-cited published documents on the topic have garnered between 1049 and 3702 citations during the period examined in this study. The most cited published document, "Particle swarm optimization: developments, applications, and resources" by [18], has gained 3702 publications and was published in the "Proceedings of the IEEE Conference on Evolutionary Computation." This is closely followed by "Handling multiple objectives with particle swarm optimization" by [19] and "Comprehensive learning particle swarm optimizer for global optimization of multimodal functions" by [20] with 3082 and 2818 publications, respectively. Overall, the data in Table 1 shows that PSOA research studies are highly cited, which indicates high research impact and scholarly interest. Therefore, it is envisioned that the number of published documents, citations, and funding/financial support for topics in PSOA will increase even further in the coming years. This scenario will

be stimulated by the entry of new researchers, affiliations, countries, and collaborations on the topic. To further examine the current status and future outlook on the topic, bibliometric analysis was also carried out in the PSOA Research.

3.5. Bibliometric Analysis.
Bibliometric analysis is an innovative technique used to examine the research landscape and scientific developments in any research field or topic [27, 28]. It employs mathematical/statistical tools to identify, screen, and analyze the research publications or published documents so as to elucidate the co-authorships, keywords occurrences, and (co-citations) on any given topic [29–31]. In this study, the bibliometric analysis of the topic, PSOA, was examined using the software VOSviewer (Version 1.16.17) to deduce the research landscape and scientific developments on PSOA research.

3.5.1. Co-Author Analysis.
Figure 9 shows the network visualization map for co-authorship on PSOA Research. The analysis was based on a minimum of 10 published documents and 5 citations per author. The search returned 4781 authors with 56 satisfying the required threshold and was hence selected for the co-analysis. As observed in Figure 9, the most extensive set of connected authors is 55, which resulted in 6 clusters comprising 4–15 authors each. The most prominent or red cluster consists of 15 authors with notable authors such as Zhang S., Li X., and Wang L., among others. The second-largest or green cluster consists of top researchers such as Zhang Y., Wang Y., and Zhang J., among others. However, the smallest cluster (cobalt blue) is made up of just 4 authors, including Zhang M., who, as stated earlier, is the most prolific author on PSOA research in the literature. The findings confirm that Zhang M. is not only the most prolific but also a highly influential author who has high rates of collaborations. Next, the rate/extent of collaborations among countries was also examined, as shown in Figure 10.

The analysis is based on a minimum of 10 published documents and 5 citations per country. The search results returned 88 countries with 37 satisfying the required threshold and were hence selected for further analysis. As observed, the most extensive set of connected countries resulted in 7 clusters, each with 2–10 items/countries. The most prominent or red cluster includes co-authorships/collaborations between countries such as Malaysia, Iraq, Egypt, France, Tunisia, and Saudi Arabia. However, the highest total link strength is between China and the duo United States (US), and the United Kingdom (UK), which indicates the authors in these countries have the highest number of published items/collaborations on the topic. Overall, the co-authorship analysis showed strong links between authors and countries, which suggests that PSOA research is characterized by high rates of published documents and scholarly collaborations. This observation points to a highly dynamic research landscape owing to significant scientific developments churned out annually in the field.

TABLE 1: Top cited publications on PSOA research.

| References	Title	Journal/Source title	Cited by
Eberhart and Shi [18]	Particle swarm optimization: developments, applications, and resources	Proceedings of the IEEE conference on evolutionary computation, ICEC	3702
Coello et al. [19]	Handling multiple objectives with particle swarm optimization	IEEE transactions on evolutionary computation	3082
Liang et al. [20]	Comprehensive learning particle swarm optimizer for global optimization of multimodal functions	IEEE transactions on evolutionary computation	2818
Trelea [21]	The particle swarm optimization algorithm: Convergence analysis and parameter selection	Information processing letters	2145
Robinson and Rahmat-Samii [14]	Particle swarm optimization in electromagnetics	IEEE transactions on antennas and propagation	1847
del Valle et al. [8]	Particle swarm optimization: basic concepts, variants, and applications in power systems	IEEE transactions on evolutionary computation	1726
Wang et al. [10]	Crystal structure prediction via particle-swarm optimization	Physical review B—condensed matter and materials physics	1599
Coello Coello and Lechuga [22]	Mopso: A proposal for multiple objective particle swarm optimization	Proceedings of the 2002 congress on evolutionary computation, CEC 2002	1482
Zhan et al. [23]	Adaptive particle swarm optimization	IEEE transactions on systems, man, and cybernetics, part B: cybernetics	1441
Gaing [12]	Particle swarm optimization to solving the economic dispatch considering the generator constraints	IEEE transactions on power systems	1362
Gaing [13]	A particle swarm optimization approach for optimum design of PID controller in AVR system	IEEE transactions on energy conversion	1347
Sun et al. [24]	Particle swarm optimization with particles having quantum behaviour	Proceedings of the 2004 congress on evolutionary computation, CEC2004	1227
Shi and Eberhart [25]	Fuzzy adaptive particle swarm optimization	Proceedings of the IEEE conference on evolutionary computation, ICEC	1157
Vesterstrøm and Thomsen [15].	A comparative study of differential evolution, particle swarm optimization, and evolutionary algorithms on numerical benchmark problems	Proceedings of the 2004 congress on evolutionary computation, CEC2004	1086
Van den Bergh and Engelbrecht [7]	A study of particle swarm optimization particle trajectories	Information sciences	1057
Bratton and Kennedy [26]	Defining a standard for particle swarm optimization	Proceedings of the 2007 IEEE swarm intelligence symposium SIS 2007	1049
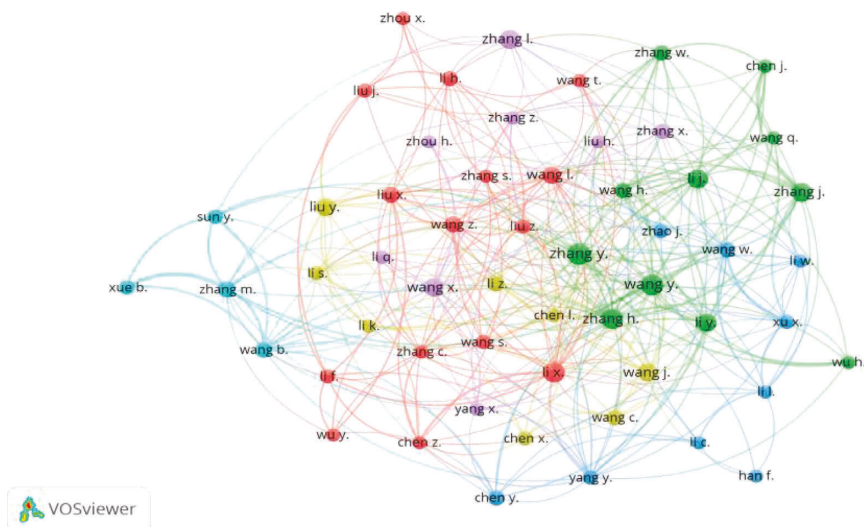
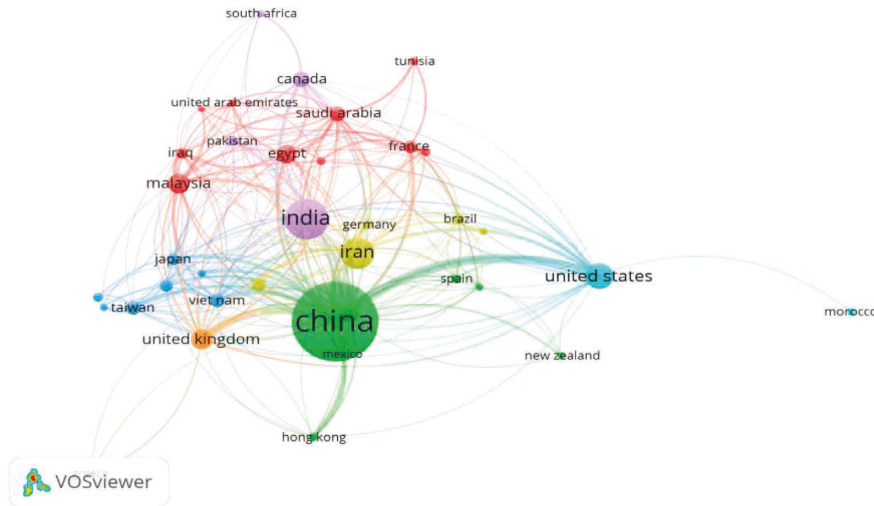FIGURE 9: Network visualisation map for co-authorship on PSOA research.

Figure 10: Network visualisation map for country-based co-authorships on PSOA research.

3.5.2. Keyword Co-Occurrence. The analysis of the occurrence of the keywords related to any field of research is another critical approach to examining the research landscape in any field of research in the literature [32, 33]. Hence, the keyword co-occurrence analysis of the PSOA research area was examined in this study. Figure 11 shows the network visualization map of the most occurring keywords on the topic.

The analysis was based on the minimum keyword occurrence of 25, which resulted in 14,347 keywords. The search results returned 126 keywords and 6 clusters, each comprising 7–36 items. As observed, the most occurring keywords are "particle swarm optimization (PSO)," "particle swarm optimization," and "optimization," which occurred 1726, 848, and 612 times with the total link strength of 7988, 4000, and 3404, respectively. The high rate of occurrence of these keywords in the search results in not unconnected to the design and executed search query and title of the study. Other notable occurring keywords deduced in the analysis are; multi-objective optimization, genetic algorithms, swarm intelligence, benchmarking, and forecasting. The primary occurring keywords in PSOA research are indicative of the correlation and overlaps between different disciplines such as computer science, computer engineering, artificial intelligence, mathematics, and statistical analysis. Therefore, it can be reasonably inferred that the topic is multidisciplinary with broad research and scientific themes.

3.5.3. Citation Analysis. The citations gained by published documents show the level or extent of their research and scientific impact. Therefore, the citation analysis of PSOA research was carried out to examine the citations rates of authors, journals/sources, and countries actively researching the topic in the literature. The author-based citation analysis was based on the search criteria of a minimum of 10 documents and 5 citations per author. The results showed that 4781 authors satisfied the required criteria, while 56 were selected for further analysis. Figure 12 shows the network

visualization map for the author-based citations on PSOA research.

The findings show that the most extensive set of connected authors is 55, which generated 6 clusters, each containing 4–15 authors. The most prominent or red cluster comprising Zhang L., Wang X, Li W., among others, is the highest cited author on the topic. The author, Zhang Y., of the cobalt blue cluster, has the highest total link strength and co-citations on the topic. Overall, the findings indicate that published documents on the topic are highly cited globally and amongst the top stakeholders in the field. In addition, the high rate of citations and co-citations indicates a high level of collaboration as well as interorganizational and inter-country research among scholars in the field. Next, the citation analysis of the most cited published documents in the field was examined. This analysis aims to elucidate the benchmark studies on the subject based on the network visualization map shown in Figure 13.

As observed, there are 16 clusters, each with 3–8 items. The most prominent or red cluster (comprising the works of Cao Y (2019)) has the highest link strength among all the clusters indicating a high rate of co-citations and consequently research impact. Similarly, the co-citations among the most active countries researching topics on PSOA were also examined, as illustrated in Figure 14. The findings indicate that China from the largest (red) cluster has the highest rate of co-citations particularly with other nations/regions such as Hong Kong, Canada, the United States, and the United Kingdom. Similarly, China has strong links with India and Iran, which have the second and third largest citations/co-citations on the topic.

3.6. Existing Works in Hybrid of PSO. Table 2 shows a summary of various existing researches on the hybrid of Particle Swarm Optimization (PSO) and Differential Evolution (DE). The combination of PSO and DE was carried out by several researchers to give room for better performance of the algorithms using various performance
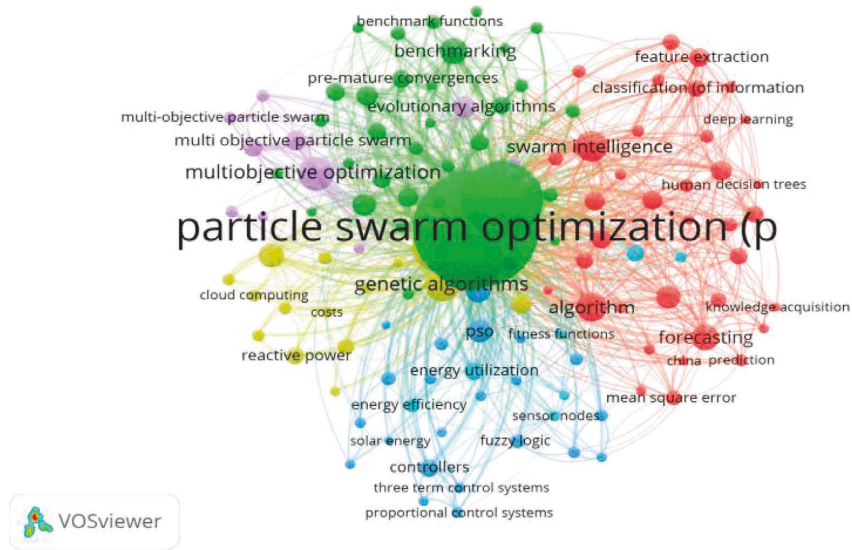
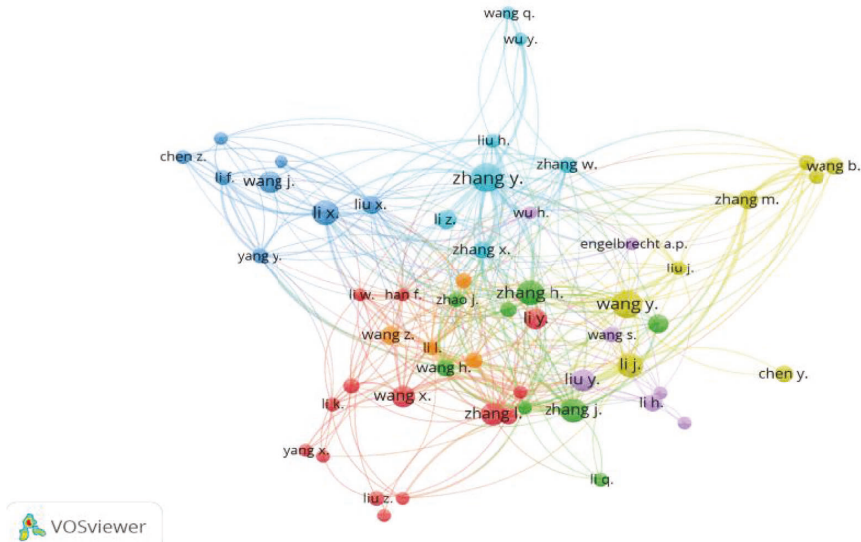FIGURE 11: Network visualization of co-occurring keywords on PSOA research.

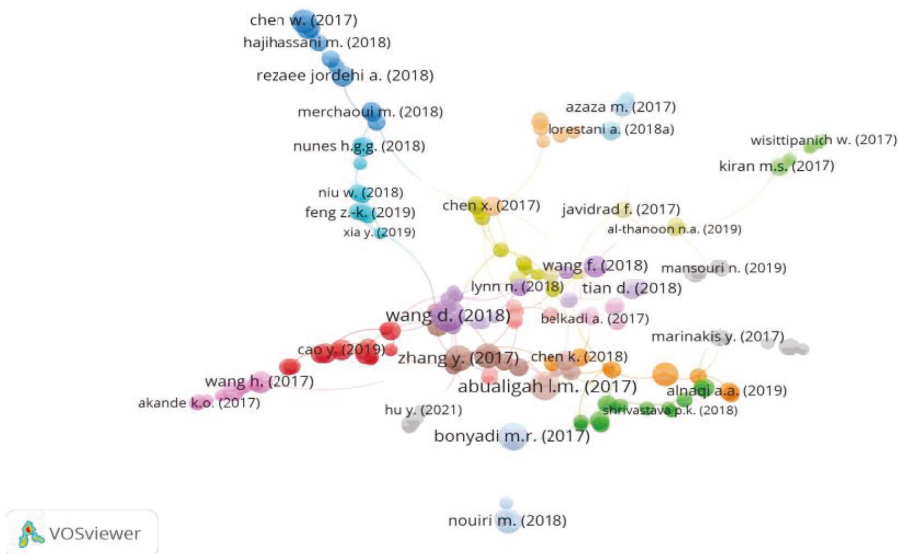FIGURE 12: Network visualization map for the author-based citations on PSOA research.

FIGURE 13: Network visualization map of the co-citations among top published/cited documents on PSOA research.
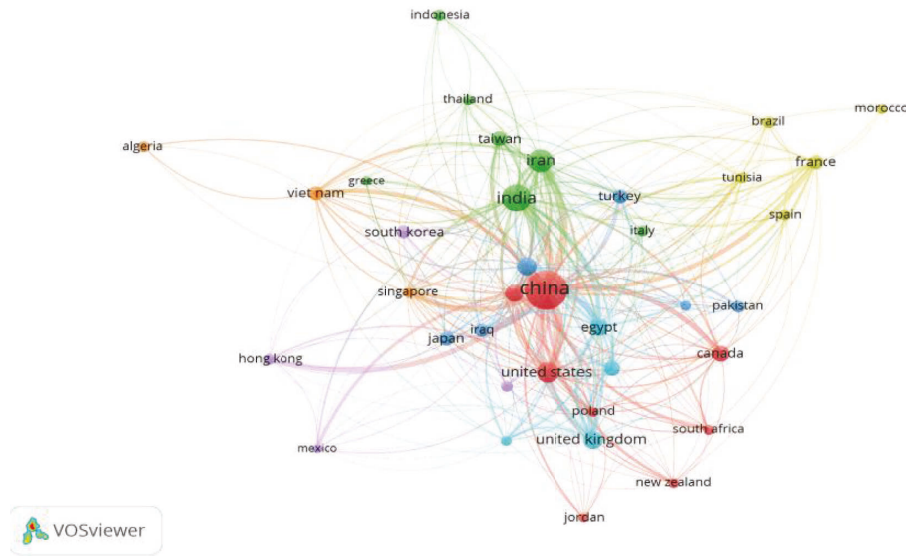
FIGURE 14: Network visualization map of the co-citations among most active countries researching PSOA topics.

TABLE 2: Summary of existing works on hybrid particle swarm optimization (PSO).

References	Techniques	Performance metrics	Pros	Cons
Liu et al. [34]	PSO-DE	Objective function values, median, mean, standard deviation	Converges quickly, it solves constrained problems	Higher cost in some problems
Iwata and Fukuyama [35]	DEEPSO	Least square error	Accuracy	Underperforming in unsTable output conditions
Yoshida and Fukuyama [36]	DEEPSO	Mean and standard deviation of objective functions	Faster convergence speed and better accuracy	Parallel distributed processing is not considered
Buba and Lee [37]	Hybrid DE and PSO	Passengers' and operators' cost	Diversity of solution, better accuracy	It is not tested on larger and more realistic problem instances with heterogeneous buses
Wang et al. [38]	DEPSO	Mean and standard deviations of the objective functions	Population diversity, higher scalability	Exploration and exploitation need improvement, implementation complexity
Dabhi and Pandya [39]	EVDEPSO	Iterations and mean execution time and mean, max, min, and standard deviation of the objective function, average ranking index	It is superior in terms of the ranking index and average ranking index as compared to the other algorithms	Tests are confined to a limited category of problems
Mirsadeghi and Khodayifar [40]	PSODE	Mean, the best, the worst, and standard deviation of the objective functions, run-time, success rate	High accuracy of solution	Improvement for the exploration and exploitation capabilities, implementation complexity
Marcelino et al. [41]	C-DEEPSO	Mean, median, and standard deviation of objective functions	Better accuracy, high scalability	Improvement for the exploration and exploitation capabilities
Tomar and Pant, 2011 [42]	MPDE	Mean, standard deviation of objective function	Better computation time	Getting trapped in local optima
Yu et al. 2014 [43]	HPSO-DE	Mean, standard deviation and T-value of objective function	Maintains diversity of the population	Slow convergence and high computation time
Lin et al. 2018 [44]	HPSODE	Mean, standard deviation of objective function	Good solution accuracy	Converging at local optima,
Too et al. 2019 [45]	BPSODE	Mean, standard deviation of the objective function	Good solution accuracy	Extra computational cost, premature convergence
Parouha and Das 2016 [46]	DE-PSO	Mean, standard deviation of objective function	Better solution accuracy	Rapid loss of diversity, converging prematurely.

evaluation metrics. The performance metrics used by most researchers displayed in the Table are Mean, the standard deviation of the objective functions, and T-value of objective functions. Quite a number of the research works described in the Table performed well in their various capacities but mostly still have some common weaknesses such as improvement for balancing the exploitation and exploration capabilities for slow convergence rate, getting stuck in local optima, premature convergence, and high computation time.

4. Conclusions

The paper presented a comprehensive analysis of the research landscape and scientific developments in the Particle Swarm Optimization Algorithms (PSOA). The study objectives were accomplished using bibliometric analysis of all the published documents indexed in the Scopus database Survey on (2001–2021) using VOSViewer. Likewise, the publication trends, significant stakeholders, top funding bodies, and cited publications on PSOA were examined over the 20-year time span of the study. The findings revealed that the published documents on PSOA increased geometrically by 21,362.50% from 8 to 1,717 from 2001 to 2021, which could be attributed to the growing applications of PSO in solving optimization problems in academia, industry, and policy. Furthermore, the most common document type for the field is "conference papers," which deviates from the norm of "articles" reported for other fields of research in the literature. Further analysis revealed that the most prolific researcher on the topic is Andries P. Engelbrecht, whereas the Ministry of Education (China) is the most active research organization. The top funding body is the National Natural Science Foundation (NSFC) of China, while the People's Republic of China is the most active research country for PSOA research in the world. Bibliometric analysis revealed that the research landscape on the topic is characterized by high levels of publications, collaborations, and citations within affiliations/organizations, and countries worldwide. Consequently, it can be rationally deduced that the topic has broad research and scientific themes that are multi-disciplinary in nature.

Data Availability

No data have been used to support the findings of the study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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