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RESEARCH ARTICLE

RFID Network Planning of Smart Factory Based on Swarm Intelligent Optimization Algorithm: A Review

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ABSTRACT With the development of intelligent manufacturing in China, Radio Frequency Identification (RFID), a key technology for smart factories, has received widespread attention. As RFID applications expand, so does the size of their networks. It makes it more difficult to ensure RFID signal coverage, leads to communication problems, and increases equipment energy consumption and costs, thereby posing challenges in the realm of RFID network planning (RNP). The RNP problem needs to consider multiple objectives and constraints such as coverage, conflicts, economic benefit, and load balance which have been proven to be optimized by swarm intelligent optimization algorithms. Therefore, this study reviews smart factories, RFID technology, swarm intelligence optimization algorithms and RFID network planning. The improvement direction of swarm intelligence optimization algorithms and factors affecting RFID network performance are also explored. In addition, it reviews and analyzes the applications of swarm intelligence algorithms to RNP problems and discusses the innovations and drawbacks of these approaches. Finally, some research limitations and directions are identified.

INDEX TERMS Smart factory, RFID network planning, swarm intelligence optimization algorithm.

I. INTRODUCTION

With the proposed strategy of "Made in China 2025", the Chinese government has continuously expanded the integrated development of information and industrialization which is called intelligent manufacturing. As an important part of intelligent manufacturing, the smart factory has attracted wide attention because it is highly efficient, energy-efficient, environmentally friendly, safe, and comfortable [1]. RFID technology is worth examining since it is an essential component of the industrial internet and the smart factory, and it is extensively applied due to its lower cost and higher performance [2], [3], [4].

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RFID technology is widely used in smart factories because of its ability to independently, immediately, and collect product data in a non-intrusive manner. This improves the visibility of information during all stages of transportation, production, and other activities [5]. However, the widespread adoption of RFID technology has given rise to a myriad of complex challenges. As the number of items to be tracked increases, so does the quantity of tags. This growth can lead to several issues, including tag coverage problems and potential limitations due to reader-to-tag distance and frequency restrictions, which ultimately impact the performance of the RFID system [6]. Therefore, it is very important to plan the number, position and other parameters of the tags and readers to ensure that everything in the workspace can be monitored, which is called RFID network planning (RNP).

TABLE 1. Parameters of literature search.

Parameter	Value
database	The China National Knowledge Infrastructure(CNKI)
theme	Induction intelligent manufacturing, Intelligent factory, Made in China 2025
time range	2005-2022
source	Peking University Core, Chinese Social Sciences Citation Index (CSSCI)and postgraduate papers

Currently, many methods for optimizing RFID network planning are based on intelligent optimization algorithms, such as the particle swarm optimization algorithm [7]. Some scholars improve on these algorithms to obtain better network planning, such as the hybrid cuckoo algorithm [8], the improved whale optimization algorithm [9], and the improved artificial bee colony algorithm [10]. Consequently, studying the swarm intelligent optimization algorithms is crucial for the widespread implementation of RFID in smart factories.

The primary aims of this review are to:

- Review research related to smart factories, RFID, and swarm intelligent optimization algorithms to gain in-depth insights into the latest developments in these relevant fields.
- Study RFID technology and analyze RFID network performance metrics.
- Investigate existing swarm intelligent optimization algorithms and methods for RFID network planning.

The remainder of this paper is organized as follows: Section II emphasizes the significance and necessity of research in smart factories, provides a detailed overview of the composition of RFID systems and discusses their application areas. The principles and improvement directions of swarm intelligence algorithms are elaborated upon in Section III. Section IV suggests the importance of RFID network planning and its optimization objectives. Section V reviews the current application status of intelligent optimization algorithms in RFID network planning. Limitations of the current research are clarified in Section VI. Finally, Section VII provides a summary and future directions.

II. RFID IN SMART FACTORIES

This section initiates the discussion on the smart factory within the framework of the "Made in China 2025" initiative, which has emerged as a prominent area of scholarly inquiry. Subsequently, it presents a concise outline of RFID technology and delineates its primary use cases. Lastly, it delves into an examination of the pivotal role played by RFID in smart factories, including its contributions to improving transparency in the manufacturing process, enhancing quality control standards, and fostering greater system adaptability. By conducting a thorough examination of the specific implementations of RFID in smart factories, the objective is to underscore its importance in the establishment of intelligent manufacturing and smart factories.

TABLE 2. High-frequency words.

No.	Word Frequency	Keyword
1	1002	Intelligent manufacturing
2	121	Manufacturing industry
3	91	Industry 40
4	83	Smart factory
5	74	Digital twin
6	72	Made in China
7	71	Artificial intelligence
8	53	intelligent
9	50	Transformation and upgrading
10	48	Vocational education
11	46	Personnel training
12	42	Internet of Things
13	39	Big data
14	33	Manufacturing power
15	24	digitization
16	24	Digital economy
17	21	Internet plus
18	20	Green manufacturing
19	18	New engineering
20	17	Robot

A. SMART FACTORY

Since the "Made in China 2025" strategy was proposed in 2015, emphasis on intelligent manufacturing has grown in all aspects of society, resulting in numerous studies and applications. This has generated a large amount of literature, making it difficult to filter through. Hence, the visual literature measurement approach is used for analysis, helping to understand the development environment and frontier hotspots in the field of intelligent manufacturing.

Taking 2015 as the time point and going back 10 years, the literature related to smart manufacturing published from 2005 to 2022 was analyzed. The search method and statistical results are shown in TABLE 1.

A total of 3259 journals and 2455 master's and doctoral theses were obtained from the CNKI database, amounting to 5961 publications. In order to enhance the precision and efficiency of the examination, the acquired literary works underwent manual scrutiny and filtration, resulting in the removal of unsuitable materials, such as those that were inaccessible, lacked a known source, or veered off the designated topic. Subsequently, a total of 2274 eligible literary works were chosen as the sample corpus for this literary scrutiny. These 2274 documents in the sample dataset were subjected to analysis using the Cite Space software, leading to the identification of 20 frequently occurring terms through statistical methods, as outlined in TABLE 2.

By conducting a systematic search for literature, sorting, and analyzing it, a data sample set in this field was acquired. Statistical analysis was performed according to the publication year, resulting in the creation of a curve chart illustrated

FIGURE 1. Number of publications from 2005 to 2022.

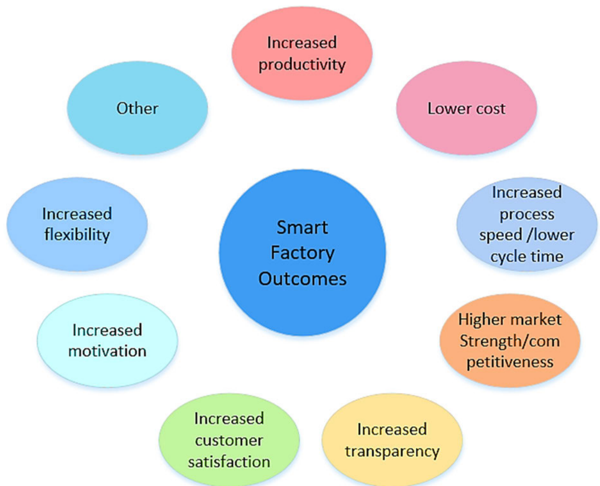

FIGURE 2. Outcomes of smart factory implementation [13].

in FIGURE 1. The graph shows the variations in the volume of literature released in this area during the period of 2005 to 2022.

Until 2012, research on smart manufacturing and smart factories was relatively limited, with fewer than ten publications annually. From 2013 to 2014, there was a clear upward trend in the amount of literature. The number of publications in these two years exceeded the previous seven years combined. During this period, the United States, Germany and China successively released the concepts of "Industrial Internet" and "Industry 4.0", which attracted a great deal of attention from Chinese industry and academia. Since 2015, the number of relevant papers has increased dramatically, and the corresponding curve has risen sharply. The increase in 2015 even reached 183% compared with the previous year, due to the release of China's national strategy "Made in China 2025" and "Guiding Opinions on Actively Promoting the Action of "Internet Plus" in 2015. With this growing trend, the number of relevant papers published in 2022 reached 350. Therefore, the research on intelligent manufacturing and smart factories is in line with the research trend.

"Dark factory", "lights-out factory" and "unmanned factory" all describe the model of smart factories, emphasizing high automation, minimizing human intervention, and ensuring a smooth and autonomous production process [11]. The production processes of the smart factory run autonomously, leveraging the latest technologies and manufacturing models. This allows for self-optimization, adaptation to changing conditions, and real-time learning, ensuring flexibility and efficiency [12]. The literature [13] presented the outcomes of the smart factory, as shown in FIGURE 2. The smart factory can effectively increase productivity, reduce costs, enhance market competitiveness, and improve transparency.

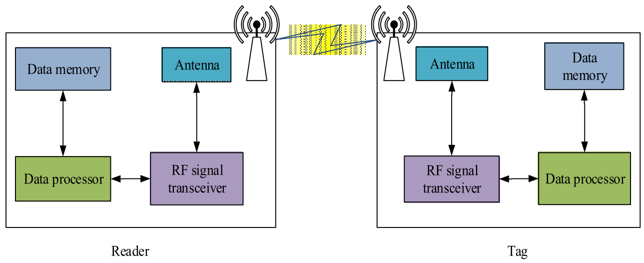

FIGURE 3. RFID system.

B. RFID SYSTEM

The RFID system's components, including tags, readers, and information management systems, are shown in FIGURE 3.

- **The information management system** is responsible for receiving the data that is transmitted by the reader, processing the intricate data, and ultimately producing valuable information.
- **The reader** comprises a data memory, a data processor, a radio frequency signal transceiver, as well as an antenna. Through its antennas, the reader has the capability to send signals, creating a reading area where the tag is recognized, with the signal strength determining the extent of the reading area. Moreover, the reader is able to engage with the computer network and transfer data to the information management system.
- **The tag** consists of data memory, data processor, radio frequency signal transceiver, and an antenna. It can identify the target item, store information about the target item, establish communication with the reader and send the data to the reader.

RFID tags can be divided into three main categories according to the way of energy supply [14]:

1) PASSIVE RFID

It belongs to the close contact identification class, such as bus card, meal card, access card, identification (ID) card, etc. Its electronic tag does not contain a battery and completely relies on the power provided by the reader to drive. Generally maintenance-free, with lightweight, small size, long life, cheaper and other advantages, but its reading distance is limited by the reader transmission power and tag chip function and other factors. The reading range is about 6 meters.

TABLE 3. RFID in smart factories.

Scenes	Applications	Benefits	Ref.
Quality Control	The RFID system collects massive production data from smart factories. After cleaning and clustering, it can extract key information and predict failure rates.	Through failure rate analysis and batch counting, it is possible to predict the location of failure, intervene in advance, and effectively improve product quality.	[3]
Warehouse Management	The RFID device on the warehouse door reads the weight of the goods written on the tag and checks it with the electronic scale to ensure accuracy.	Reduce inbound processing time to 192.8 seconds, decrease inspection staff to 1 person, effectively enhance inbound efficiency, and lower labour costs.	[21]
Production Process Tracking	The workpiece is placed on the pallet with RFID, and each machine is fixed with an RFID reader to track the order status and schedule it through Artificial Intelligence(AI).	Improve scheduling efficiency and manage the production process	[22]
	Place RFID readers in the workshop, place RFID tags on workpieces and equipment, read or update status information through radio frequency signals, transmit relevant data to the remote server database, and receive commands from the host computer.	RFID realizes real-time tracking of workpiece processing progress in smart workshops through real-time transmission of process information, encrypted transmission, and automated supervision.	[23]
	Place RFID tags on the ground or in objects, configure the automated guided vehicle with an RFID reader, and use RFID technology to control the automated guided vehicle to change paths, stop and perform specific operations.	Realizes motion control and object recognition, improving the adaptability and efficiency of automated guided vehicles	[24]

2) ACTIVE RFID

It belongs to the category of long-distance automatic recognition and has significant applications in intelligent transportation, smart cities, and other fields. Its electronic tag can be battery-driven to actively transmit signals to RFID readers, transmit data, and read a long distance, up to 30 meters, but the life is limited, and the price is high.

3) SEMI-ACTIVE RFID

Combined with the advantages of active RFID and passive RFID, the use of low-frequency short-range accurate positioning, and microwave long-distance identification upload data. When the circuit that maintains the data in the tag or performs remote work, the battery in the tag is used for power supply with little energy consumption.

Because of the high demand for the number of RFID tags and the associated growth in costs, the latest research has examined an RFID chip-less technology, which does not require the use of chips to store information, decreasing the cost of usage and prolonging the service life [15].

C. RFID SYSTEM APPLICATION

RFID technology has been widely used in supply chain management and fashion supply chains. It is indispensable in modern agriculture to track vital indicators like humidity, temperature, humidity, and light intensity to realize smart irrigation with RFID technology [16]. In the large-scale farming industry, RFID technology can monitor the growth details and health status of livestock to improve breeding efficiency [17]. The field of food also benefits greatly from RFID technology, which may be used to monitor food quality and freshness. Smart roads, autonomous driving and telematics in smart transport are also based on innovative applications of RFID technology in the transport industry, such as the use of systems based on magnetic loops and RFID tags to establish short-range communication between vehicles and infrastructure to extract information from the vehicle, like speed, length or direction of traffic [18].

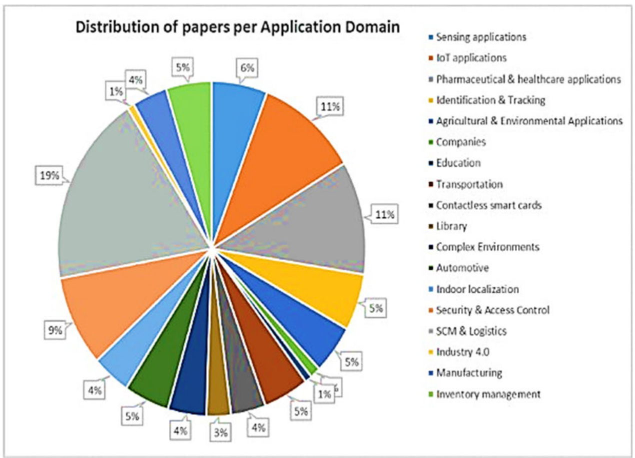

FIGURE 4. Application domain [20].

A study by Haibi et al. shows that 24% of RFID research is focused on hardware design and performance, 23% on security and privacy, and 22% on RFID applications and technology presentation [19]. Another study in 2021 shows that RFID technology is widely applied in many domains. As shown in FIGURE 4, Supply Chain Management (SCM) & Logistics accounted for the highest proportion at 19%, followed by Pharmaceutical & healthcare applications and the Internet of things accounted for 10%, Industry 4.0 and manufacturing-related each accounted for 5% which is a small proportion [20]. With the further advancement of Industry 4.0 and Made in China 2025, it is necessary to

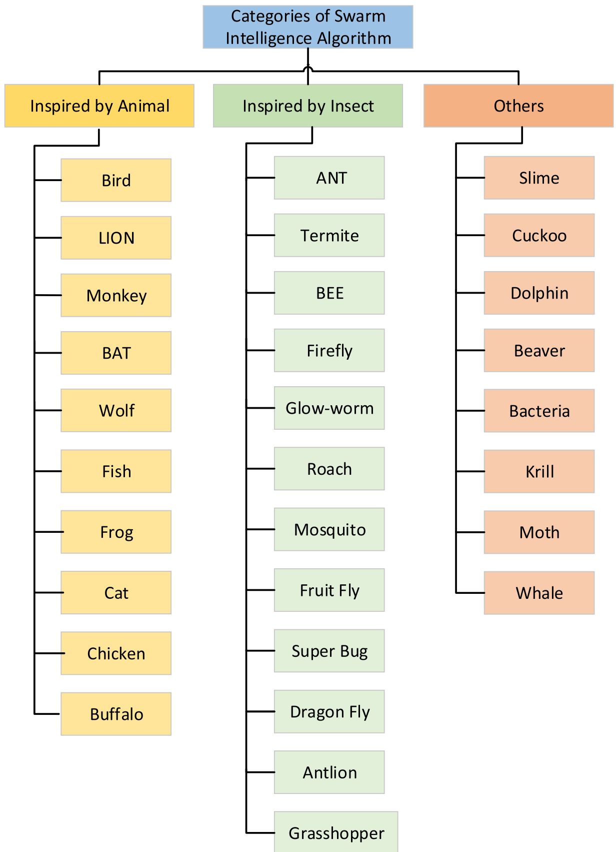

FIGURE 5. **Categories of swarm intelligence algorithm [26].**

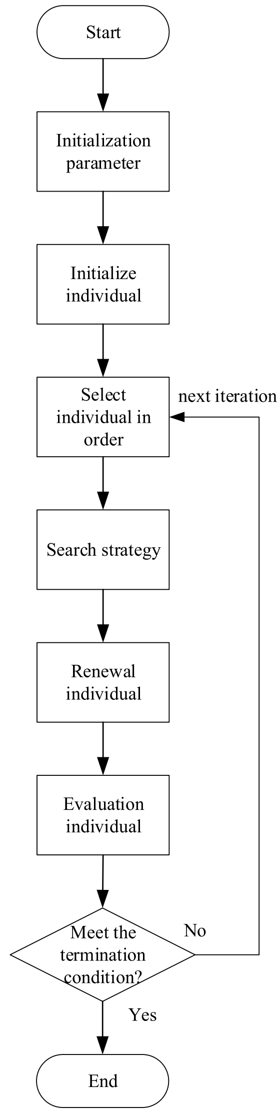

FIGURE 6. **Swarm intelligence algorithm flow chart [27].**

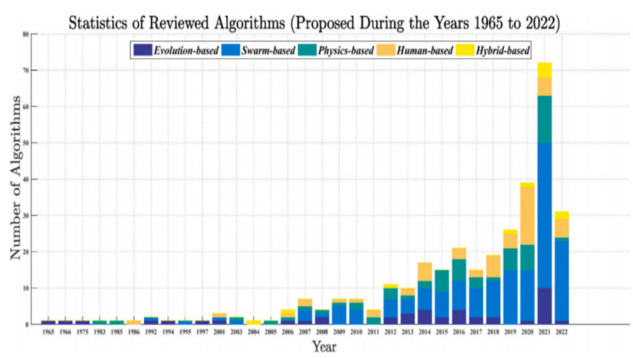

FIGURE 7. **Statistics of algorithms proposed during the years 1965–2022 [29].**

strengthen the research of RFID in the field of intelligent manufacturing.

RFID technology has become a key technology in smart factories, providing real-time data collection and item tracking functions. RFID technology helps factories improve production efficiency, reduce costs, and improve quality and safety. To study the specific application of RFID technology in smart factories, relevant literature in Scopus and Web of Science (WOS) databases was analyzed as shown in TABLE 3.

III. SWARM INTELLIGENCE OPTIMIZATION ALGORITHM

This section will present an overview of the current landscape of swarm intelligence optimization algorithms, with a particular emphasis on two specific ones. It will start by briefly explaining the fundamental principles of swarm intelligent optimization algorithms and then, enumerate recently developed swarm intelligent optimization algorithms over the past few years, as well as improved algorithms for existing algorithms. Following that, a concise overview of the sparrow search algorithm, including basic ideas, algorithmic process, and applications will be provided. After that, the basic principles, algorithmic process, and optimization strategies of the firefly algorithm will be introduced.

An optimization problem is to find the best solution in different possibilities under certain conditions [25]. For example, in engineering design, relevant parameters need to be adjusted to ensure that the design solution meets the design requirements while reducing costs. As another example, in the path planning problem, it is necessary to find the best path from the starting point to the endpoint in a given

TABLE 4. Emerging novel swarm intelligence algorithms (2020-2023).

Ref.	Year	Algorithm	Inspiration	Application
[30]	2020	Mayfly optimization algorithm(MOA)	Inspired by plankton, the algorithm simulates the flight behaviour and mating process of mayflies	38 mathematical benchmark functions and a real-world discrete flow-shop scheduling problem.
[31]	2020	Bald Eagle Search (BES)	Inspired by vulture hunting, the algorithm simulates vulture hunting behaviour or intelligent social behaviour	benchmark test functions
[32]	2020	Black Widow Optimization Algorithm (BWOA)	Inspired by the mating behaviour of black widow spiders, this algorithm simulates the life cycle of black widow spiders.	SHE set of equations
[33]	2021	Dingo Optimization Algorithm (DOA)	Inspired by the hunting strategies of wild dogs, simulate wild dog persecution attacks, grouping strategies and scavenging behaviour.	benchmark problems, classical design engineering problems, and optimal tuning of a Proportional-Integral-Derivative (PID) controller
[34]	2021	Wild Horse Optimizer (WHO)	This algorithm mainly searches for optimization by simulating the life behaviours of wild horse populations, such as eating grass, chasing, mating, etc.	CEC2017 and CEC2019
[35]	2021	Chameleon Swarm Algorithm (CSA)	Inspired by the dynamic behaviour of chameleons as they search for food on trees, deserts and near swamps	sixty-seven benchmark test functions and five constrained and computationally expensive engineering design problems.
[36]	2022	Mycorrhiza Tree Optimization Algorithm (MTOA)	Inspired by the relationship between trees and mycorrhizal networks (MNs), this algorithm simulates the interactions between them such as defence, communication, resource exchange, and habitat colonization.	36 mathematical functions
[37]	2022	Zebra Optimization Algorithm (ZOA)	Inspired by the zebra's foraging and defensive behaviour against predator attacks, the algorithm simulates the zebra's foraging behaviour of preferentially choosing grass and sedge, as well as the behaviour of zebras choosing escape strategies or attack strategies in the face of different predators.	68 benchmark functions and four engineering design problems, including tension/compression spring, welded beam, speed reducer, and pressure vessel.
[38]	2022	Beluga Whale Optimization (BWO)	Inspired by the behaviour of beluga whales, the algorithm simulates the behaviour of beluga whales swimming, being preyed on, and falling whales.	30 benchmark functions and 4 engineering problems.
[39]	2022	Artificial Hummingbird Algorithm (AHA)	Inspired by the behaviour of hummingbirds, this algorithm simulates the special flight skills and intelligent foraging strategies of hummingbirds	two sets of numerical test functions and ten engineering design cases.
[40]	2022	Dwarf Mongoose Optimization (DMO)	Inspired by the foraging behaviour of the dwarf mongoose, this algorithm simulates the seminomadic behaviour and compensatory adaptation.	CEC 2020 benchmark functions and 12 engineering optimization problems.
[41]	2022	Prairie Dog Optimization (PDO)	Inspired by the behaviour of the prairie dogs in their natural habitat, this algorithm simulates the prairie dogs' foraging, burrow-build activities and communication skills.	22 classical benchmark functions,10 CEC 2020 test functions and 12 engineering design problems
[42]	2023	Nutcracker optimizer algorithm (NOA)	Inspired by the behaviour of star finches, this algorithm simulates the behaviour of star finches in collecting and storing food in summer and autumn and searching for food storage locations in spring and winter.	CEC-2014, CEC-2017, and CEC-2020 and five engineering design problems.
[43]	2023	Spider Wasp Optimizer (SWO)	The algorithm simulates the hunting, nesting and mating behaviours of female spider wasps	standard benchmark, CEC2014, CEC2017, CEC2020 and two classical engineering design problems
[44]	2023	Gold rush optimizer (GRO)	Inspired by the gold rush, the algorithm simulates the behaviour of gold diggers prospecting for gold.	29 benchmark tests and 3 real engineering problems
[45]	2023	Crayfish Optimization Algorithm (COA）	The algorithm simulates the summer resort, competition and foraging behaviours of crayfish.	23 standard benchmark functions, CEC2014 and five engineering problems
[46]	2023	Piranha Foraging Optimization Algorithm （PFOA）	Inspired by the flexible foraging behaviour of piranha schools, this algorithm divides their foraging behaviour into three modes: local swarm attack, bloodthirsty swarm attack and scavenging foraging.	27 CEC benchmark functions and four real engineering design optimization problems

TABLE 5. Improvement of existing swarm intelligence algorithms.

Ref.	Year	Algorithm	Improvement	Application	Evaluation
[48]	2023	Artificial bee colony slime mould algorithm (ISMA)	Introduce adaptive adjustable feedback factor and crossover operator	CEC03、CEC06、CEC19、CEC26 and fault location of distribution network	Enhance convergence speed and accuracy. Improved positioning accuracy and robustness in fault location
[49]	2023	HWOA-CHM (WOA)	Introduce the chameleon-hunting mechanism into the whale algorithm	CEC 2022 benchmark test set	effectively improve the convergence speed and accuracy and reflect excellent local search capabilities.
[50]	2023	modified artificial hummingbird algorithm (mAHA)	introduce the opposition-based learning (OBL) strategy during the initialization phase; use the local escape operator (LEO) operator to change the solutions during the iteration	CEC'2020 test suite	enhance search efficiency, overcome limitations, and minimize the cost function.
[51]	2023	Improved hybrid grey wolf optimization algorithm (IHGWO)	use Dimension Learning-Based Hunting (DLH) Search Strategy so that neighbourhood members can share information	23 benchmark functions, CEC2022 benchmark functions and the Friedman test.	Higher convergence speed and accuracy, improving local search ability in the later stage of the algorithm
[52]	2023	Hybrid multi-group stochastic cooperative particle swarm optimization algorithm (HMSCPSO)	The population is divided into three groups, each group uses different strategies, and two groups use the chaotic mutation strategy and the Lévy flight strategy respectively.	27 widely used benchmark functions and single-diode, double-diode, triple-diode, and PV module models,	contains three groups with different search strategies, which increase diversity through information exchange, thereby improving algorithm performance.
[53]	2023	A novel firefly algorithm based on a hierarchical strategy (HSFA)	Divide the population into elite groups and non-elite groups and adopt different attraction strategies respectively.	18 benchmark functions of the pressure vessel design and speed reducer design problems	Improve exploration and development capabilities, but the value of parameter K requires prior experience

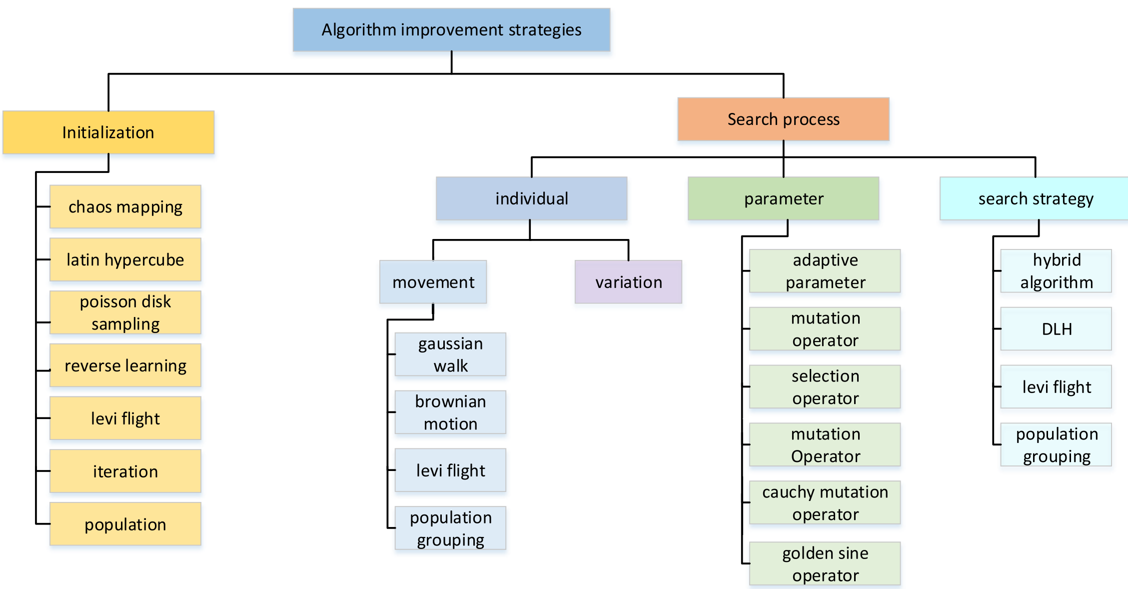

FIGURE 8. Improvement of existing swarm intelligence algorithms.

space to optimize performance indicators, such as shortest distance, shortest time, or minimum cost, while satisfying constraints.

In order to solve the complex optimization problems, researchers observe the social law of biological nature, group behaviour, and simulate the survival of the fittest rules of biological survival and put forward a series of swarm intelligent optimization algorithms, as shown in FIGURE 5. The swarm intelligence algorithms are divided into three types in reference [26]. Numerous animal-inspired algorithms exist.

For example, the bat algorithm simulates the foraging behavior of bats; the fish swarm algorithm simulates the foraging aggregation and chasing behavior of the fish group, and the chicken swarm optimization simulates the hierarchical order and behavior of chicken flocks. Some algorithms are inspired by insects, such as the ant colony algorithm simulating ant collective track-finding behaviour and the artificial bee colony algorithm simulating the honey-gathering behaviour of bees. There are also algorithms based on other biological groups, like the flower pollination algorithm simulating flower pollination behaviour.

The swarm intelligence optimization algorithm steps are shown in the FIGURE 6.

The swarm intelligence optimization algorithm is an effective method to resolve challenging optimization issues due to its easy implementation, good robustness, few parameter settings, strong adaptability, and fast convergence rate. However, there are still some defects in solving complex optimization problems, and advanced ideas need to be introduced for improvement [28].

A comprehensive review of intelligent algorithms in the past 60 years is presented [29]. As can be seen from FIGURE 7, research on swarm intelligence algorithms shows a significant growth trend. This trend demonstrates the growing interest in the application and superior performance of swarm intelligence algorithms in solving various problems.

According to TABLE 4, many novel and efficient swarm intelligent algorithms have emerged since 2020. The introduction of these algorithms not only enriches the methodology of intelligent optimization but also plays an important role in solving complex problems and responding to changing challenges.

Researchers not only propose a variety of new swarm intelligent algorithms but also focus on improving existing algorithms to enhance their performance, as shown in TABLE 5, including but not limited to search capabilities, convergence speed, adaptability, etc. This reflects the field's continued focus on addressing practical challenges, laying a solid foundation for advancements and practical applications in the realm of swarm intelligent optimization.

The improvement of the algorithms is primarily reflected in the two aspects shown in the figure, namely, the initialization part and the search part of the algorithm, as shown in FIGURE 8.

Initialization is the first step in the algorithm, and it is also a very important step because the final optimal solution will depend on the initial solution to a certain extent. Especially when the initial solution is close to the true optimal solution, the convergence speed can be improved, and the optimal solution can be found quickly. However, if the initial solution is distributed in a hopeless area, it may cause the algorithm to fall into the local optimal solution and miss the global optimal solution [47].

Generally, the population is randomly distributed in the search space. In order to optimize the initial solution, methods such as chaotic mapping, reverse learning, Levi's flight, Latin hypercube, Poisson disk sampling (PDS), etc. are used to increase the coverage of the initial solution to the problem search space so that can better discover the global optimal solution.

The population size and the number of iterations also have a certain impact on the performance of the algorithm [47]. For example, the DE-a algorithm can show better performance in most cases when the population is 100 and the number of iterations is 6000.

The optimization of the search process part is mainly based on individuals, parameters, and search strategies.

Individuals are the basic unit of search in optimization algorithms. The movement of individuals in the search space has an important impact on the performance of the algorithm. If all individuals are attracted by local suboptimal solutions, it will be difficult to jump out of the local suboptimal solutions to find the global optimal solution. Therefore, when individuals move, use Strategies such as Levi's flight and Brownian motion enable individuals to explore more extensively in the search space and seek global optimality; or mutate individuals and make certain changes to individual coding to increase the diversity of the population and improve search capabilities.

The parameters in the algorithm directly affect the algorithm's performance. By adjusting and optimizing parameters, the performance of the algorithm can be improved. For example, the artificial bee colony slime mould algorithm introduces adaptive adjustable feedback factors and crossover operators to enhance convergence speed and accuracy [48].

In addition to this, some other search strategies can improve algorithm performance. For example, mixing other algorithms and taking advantage of other algorithms to improve algorithm performance. For example, the HWOA-CHM algorithm introduces the chameleon hunting mechanism into the whale algorithm, effectively improves the convergence speed and accuracy, and reflects excellent local search capabilities [49].

A. SPARROW SEARCH ALGORITHM

Sparrow Search Algorithm (SSA) proposed by Xue and Shen from Donghua University in 2020, mainly simulates the foraging and anti-predation behaviours of sparrow groups [54]. The task of the whole sparrow population is to complete the foraging. Individual sparrows in the population are typically divided into explorers and followers. Explorers are responsible for finding food and providing foraging areas and directions for the entire sparrow population, while followers obtain food through explorers. However, if the followers find better food resources, they will convert to explorers. In the natural state, when a sparrow in the group finds a predator around, one or more individuals in the group will raise an alarm sound to remind the sparrow in the group to avoid danger, such sparrows are called vigilant, generally accounting for 20% of the entire population [54].

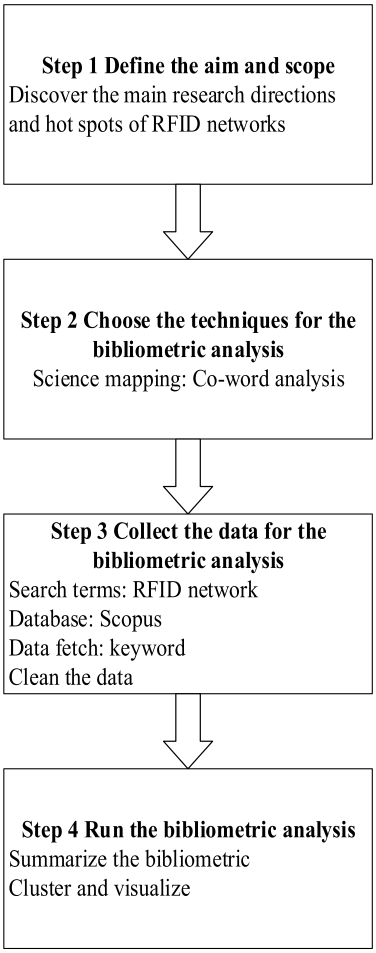

FIGURE 9. The bibliometric analysis procedure [65].

TABLE 6. High-frequency words.

No.	Word Frequency	Keyword
1	233	RFID Networks
2	147	RFID Network Planning
3	64	Optimization
4	55	Radio Waves
5	48	RFID Readers
6	47	Collision Avoidance
7	47	Algorithms
8	46	Internet Of Things
9	45	RFID Systems
10	44	Particle Swarm Optimization
11	36	Network Protocols
12	34	Genetic Algorithms
13	33	Wireless Networks
14	32	Cryptography
15	30	Middleware
16	29	Radio Navigation
17	26	Sensor Networks
18	26	RF-ID Tags
19	26	Network Security
20	24	Ubiquitous Computing
21	23	Wireless Sensor Networks
22	22	Wireless Telecommunication Systems
23	22	Evolutionary Algorithms
24	22	Artificial Intelligence
25	22	Anti-collision Protocols
26	21	Supply Chains
27	21	Radio Systems
28	21	Mobile Phones
29	20	Swarm Intelligence
30	20	Authentication

The Sparrow Search Algorithm flow is as follows:

Step 1: Initialize the population and the number of iterations.

Step 2: Calculate the fitness values and sort them.

Step 3: Update the explorer location.

Step 4: Update the follower positions.

Step 5: Update the Vigilante location.

Step 6: Calculate the fitness value and update the sparrows' position.

Step 7: If the stop condition is satisfied, exit and output the result, otherwise, repeat Step 2-6.

SSA is an optimization model based on the behaviour of sparrow foraging and hiding natural enemies, and the algorithm has good robustness. However, when solving complex problems and real engineering optimization problems, the performance of local search is poor, and the optimal solution is easily ignored. Therefore, different scholars have improved the sparrow search algorithm.

Lv et al. proposed a Chaotic Sparrow Search Optimization Algorithm (CSSOA) combining Tent mapping and Gaussian variation, which used Tent mapping to optimize the initial population distribution and choose to perform Gaussian variation or Tent mapping disturbance on individual sparrows according to the distribution of population individuals in the iterative process [56].

Li et al. proposed a multi-strategy collaborative Improved Sparrow Search Algorithm (ISSA), which uses a boundary learning strategy that incorporates transfer probability to reduce the degree of aggregation of the discoverer and expand the search scope; introduces a hybrid particle swarm mechanism to solve the problem that the sparrow follower is prone to be attracted by the position of the discoverer and fall into the local optimum; and introduces a fuzzy logic-based stochastic difference strategy that enhances the algorithm's ability to jump out of the local optimum [57].

Ma Xiaojing et al. proposed a sparrow optimization algorithm based on Circle chaotic mapping and random walk, which introduces chaotic mapping in the initialization phase to make the population uniformly distributed and enhance the racial diversity, and adopts random walk for the optimal sparrow location to enhance the global search capability of the algorithm [58].

B. FIREFLY ALGORITHM

In the wild, fireflies shoot out flashes of light to attract food or to communicate with each other. Based on this

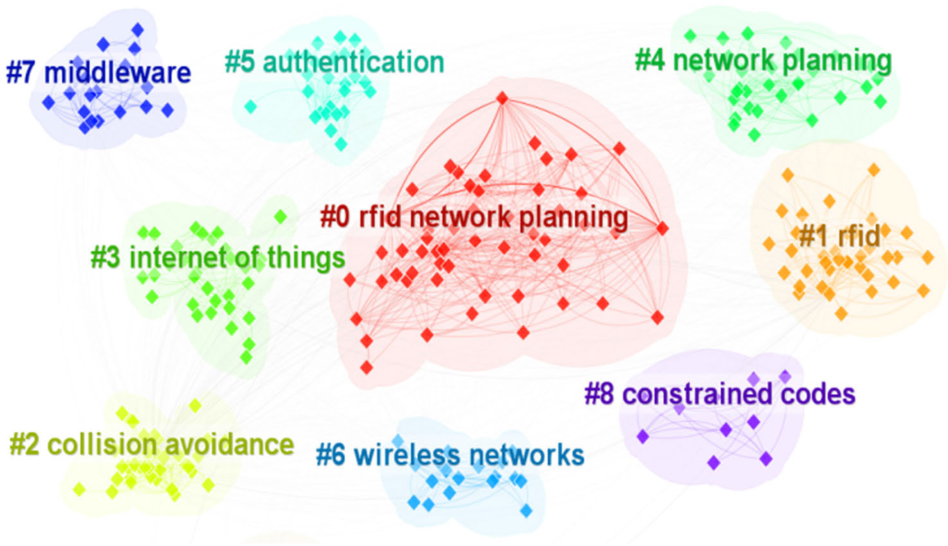

FIGURE 10. Keyword clustering in the RFID network.

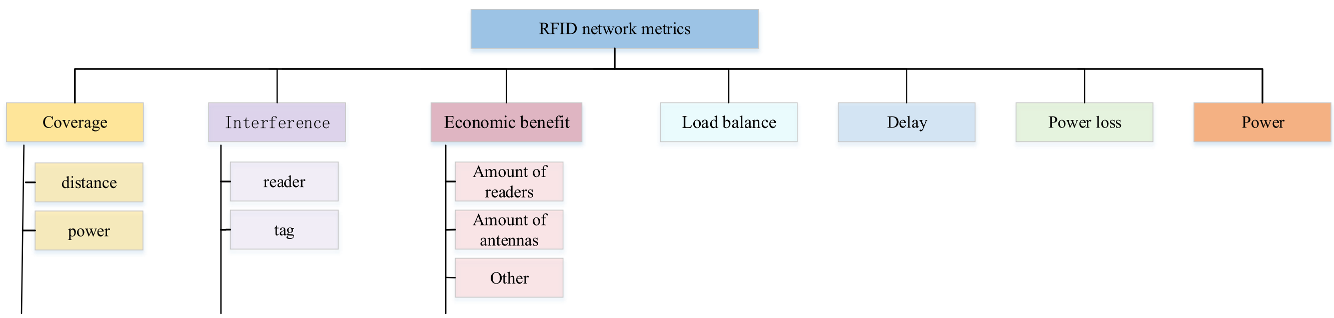

FIGURE 11. Performance metrics for RFID networks.

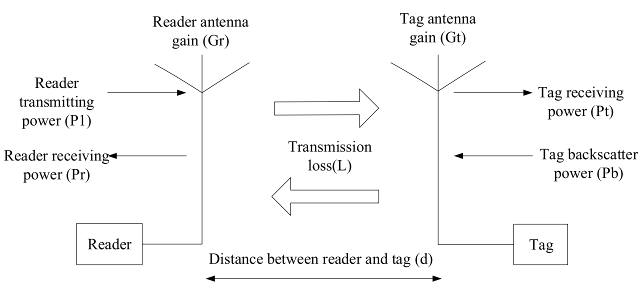

FIGURE 12. Radio frequency identification signal propagation model.

behaviour, Xinshe Yang, a scholar from Cambridge, UK, proposed the Firefly algorithm, which has the advantages of fewer parameters, high efficiency, easy implementation, etc., and has attracted wide attention. Much literature related to the application and improvement of the Firefly algorithm has appeared.

Firefly optimization algorithm is a biological heuristic optimization algorithm designed to simulate the movement and light of actual fireflies [59].

The Firefly algorithm flow is as follows:

Step 1: Initialize the algorithm parameters, including the population size, the maximum number of iterations, and the state vector of the firefly individual.

Step 2: Calculate the absolute brightness (initial brightness) of the firefly, that is, the fitness value. Generally, the value of the objective function is used to represent the absolute brightness of fireflies, and it is sorted to find the optimal solution.

Step 3: Update the firefly position. The low-light fireflies are attracted to the high-light fireflies and move towards them. Because of the loss of firefly light propagation in the air, the farther the light propagation, the smaller the brightness.

Step 4: Recalculate the absolute brightness of fireflies and repeat the process until iteration is complete.

The Firefly algorithm is one of the most popular swarm intelligence optimization algorithms at present, which is suitable for various optimization problems, especially continuous optimization problems, attracting many scholars to study and improve it to seek better performance and wider application [60]. The improvement of the Firefly algorithm mainly has the following directions:

1) ADAPTIVE
Introducing an adaptive mechanism that enables the algorithm to adjust its behaviour in different optimization phases or situations. It helps to improve the robustness and convergence speed of the algorithm [61], [62].

2) LOCAL SEARCH
Firefly algorithm has the disadvantage that it is easy to fall into local suboptimal. Combining the local search strategy with the Firefly algorithm can improve the local search ability to better find the local optimal solution [63].

3) HYBRID ALGORITHM
The Firefly algorithm is combined with other optimization algorithms, such as the ant colony algorithm, particle swarm algorithm, etc., to give full play to their advantages [64].

IV. RFID NETWORK PLANNING
This section first conducts a literature analysis on RFID networks and concludes that the research hotspot is RFID network planning. Then, the key indicators and their mathematical expressions in RFID network planning are introduced.

As mentioned in the previous section, RFID, with its ability to read data without direct linear contact, has been widely used in many fields. However, with the continuous advancement of technology and the increasing richness of application scenarios, a single RFID tag and reader cannot meet complex needs. Multiple RFID tags and readers need to work together, forming an RFID network.

To delve into the research directions and hotspots within the RFID network domain, bibliometric analysis is employed. This involves systematically collecting and analyzing relevant literature and utilizing the CiteSpace software to quantitatively showcase the research landscape of this field. Subsequently, the results will be presented using visualization techniques, such as network graphs, to provide a comprehensive and intuitive overview of the structure of research within the RFID network domain. The bibliometric analysis procedure is shown in FIGURE 9. Keywords from these articles were subjected to frequency analysis, with the top 30 high-frequency keywords presented as illustrated in TABLE 6.

- **RFID Network Planning:** As the most prominent cluster in the graph, it signifies that RFID network planning is the central topic of current research.
- **Optimization Research:** Keywords ranging from "optimization problems", "multi-objective optimization", to "optimization algorithms" reveal the predominant role of optimization in RFID networks.
- **Algorithm Application:** Including "Particle Swarm Optimization", "Genetic Algorithms" and "Heuristic Algorithms," all point to the profound foundation of algorithms in RFID research.
- **Collision Issues:** Keywords such as "collision avoidance", "anti-collision protocols" and "reader anti-collision" clearly indicate collision as a major technical challenge in the RFID field.
- **Security:** Terms like "cryptography", "network security", "data security" and "RFID security" emphasize the critical importance of security in RFID research.
- **Wireless Communication Technology**: From "radio waves" and "wireless networks" to "radio systems" they comprehensively showcase the inseparable relationship between RFID and wireless technology.

From the cluster analysis in FIGURE 10 and the high-frequency words in TABLE 6, it is evident that RFID network planning, as the core area of RFID network research, is of paramount importance. In practical applications, RFID network planning focuses on how to effectively deploy and manage RFID devices to achieve the best reading efficiency, reduce conflicts, and optimize network performance.

The performance metrics for measuring RFID networks are shown in FIGURE 11.

A. COVERAGE
The ratio of covered tags to all tags is known as coverage. In an RFID network, coverage is a key indication. There are two ways to assess coverage: one is based on the distance between the reader and the tag, and the other is based on power.

The distance-based method typically employs a Boolean model as follows [66].

$$C_v = \begin{cases} 1, & dist\,(R, T) \leq r' \\ 0, & otherwise \end{cases} \tag{1}$$

where, dist(R, T) is the distance between the reader and the tag, r' is the reading range of the reader. Tags within the reading range of the reader can be read by the reader, while tags outside the reading range cannot be read.

Power-based evaluation detects whether the transmit power and receive power meet the threshold. This helps determine whether normal communication between the tag and the reader is possible, that is, whether the tag can be covered by the reader. The RFID communication model adopts a bidirectional communication link, as illustrated in FIGURE 12 [67].

The definition of tag receive power is presented in the following Formula 2:

$$P_t\,[dBm] = P_1[dBm] + G_r[dBi] + G_t[dBi] - L[dB] \tag{2}$$

In this context, P_1 represents the transmit power of the reader, G_r and G_t denote the gains of the reader and tag antennas, respectively.

L signifies the attenuation factor in the Friis equation, defined as Formula 3.

$$L[dB] = 10\log[\left(4\pi/\lambda\right)^2 d^n] + \delta[dB] \tag{3}$$

where d represents the distance between the reader and the tag.

The received power of the reader is as Formula 4:

$$P_r[dBm] = P_b[dBm] + G_r[dBi] + G_t[dBi] - 20\log(4\pi d/\lambda) \tag{4}$$

TABLE 7. RFID network planning based on swarm intelligence algorithm.

Ref.	Problem Statement	Methodology/Algorithm	Constraints	Evaluations
[66]	number of readers, interference, power and load balance.	a hybrid particle swarm optimization algorithm (HPSO-RNP)	50m×50m: r30,3r50, r100,c30,c50,c100 150m× 150m: r500,c500;	Compared with other methods, the proposed method has better performance among the four indicators, and when the number of tags increases, full coverage can be achieved, and the number of readers can be automatically optimized
[67]	coverage, interference, redundancy and the number of antennas	hybrid approach RAE-NNA (Redundant Antennas Elimination and Neural Network Algorithm)	c30 c50 r30 r50	The proposed method is more reliable and efficient and also deploys the useful antennas better. However, the experimental results only give the average and optimal values. It is better to give the variance of the results or other distribution parameters to show the stability of the results.
[68]	coverage, the readers' interference, load balance, redundant reader's elimination, and power losses	Self-Learned Invasive Weed-Mixed Biogeography based optimization (SLIWMBBO)	50m x 50m: r50,r100,r200	Self-learning strategies are introduced into biogeography-based optimization (BBO) and the Hybrid Invasive Weed-Biogeography based optimization (HIW-BBO), which have never been used in the RNP field, to enhance algorithm performance. Compared with the RNP algorithm based on HIW_BBO and the RNP algorithm based on BBO, SLIWMBBO provides the best reader allocation, achieves full coverage, has zero reader interference, the smallest number of deployed readers, and the smallest power loss and balanced load.
[70]	Coverage Tags, Interference Between Readers, Power Radius of Readers, and Load Balancing	BIRCH Chaotic Particle Swarm Optimization (BCPSO)	The radius of the RFID reader is taken as a random value between 8-15 meters: (45*40)m: 30 tags and 3 readers; (65*70)m: 50 tags and readers; (90 * 90 m: 100 tags and 4 readers; The radius of the RFID reader is considered the same value for all readers: (40*40)m: 30 tags and 3 readers; (55*55)m: 50 tags and 4 readers; (105 * 105 m:100 tags and 4 readers;	The algorithm can optimize the goals, enhance tag coverage, avoid interference between readers, minimize the radius power of RFID readers and minimize load balancing of clustering points in the RFID system. However, the selected experimental scenario is not representative and lacks comparison with other algorithms.
[71]	coverage, interference, power, and load balance	a novel two-level master–slave RNP model and a novel algorithm called H-MOABC based on the ABC algorithm	cd100 and rd500	The proposed algorithm outperforms NSGA-II and MOEA/D in multi-objective optimization. However, it needs to be compared with more advanced algorithms to highlight its superiority.
[72]	coverage, accuracy, interference from interrogation and disturbance from FSF	an improved CSO algorithm called EGCSO for solving the RNP problem	12m×8m×3m	EGCSO shows superior effectiveness compared with six traditional algorithms. However, when solving the RFID network planning problem, only the two optimization goals of coverage and localization accuracy are considered, and various indicators of RFID network planning are not fully considered.
[73]	coverage, interference, power, and load balance	a hybrid algorithm called MASSA based on the mayfly sparrow algorithm which introduced chaotic map and Lévy flight	30m×30m; reader: 3-6; tag: 50-90	The MASSA exhibits superior planning performance, economy, and robustness when compared to SSA, ISSA, MA, PSO, and GWO. However, the approach of optimizing multiple objectives into a single one using the weighted coefficient method is subjective and lacks objectivity, relying on researchers' experience.
[74]	coverage, interference, load balance, and power	a multi-objective mayfly optimization algorithm based on dimensional swap variation to optimize two and three objective functions at the same time which would achieve Pareto optimal solutions	30m×30m; reader: 6; warehouse indoor: 30m×18.80m	DSV-MOMA can effectively reduce interference and achieve satisfactory load balancing and power while guaranteeing higher coverage. However, the experimental problem is small in scale, with only 6 readers, and it is better to verify the scalability of the algorithm on a large-scale RFID network.
[75]	tag coverage, load balance, economic benefits and interference	an improved element herding algorithm (IEHO)	static RFID tags:100 ; movable RFID reader:10	compared with the bacterial foraging optimization algorithm (MC-BFO), particle swarm optimization (PSO) and constrained bat algorithm (BA-OM), the coverage. The load balance and the reader interference problem are well improved.

TABLE 7. *(Continued.)* **RFID network planning based on swarm intelligence algorithm.**

				However, the number of times the algorithm is run only once, and the reliability of the results cannot be guaranteed. It is better to repeat the run multiple times to take the average or variance.
[76]	tag coverage	particle swarm optimization (PSO)	150m×150m; patients:40; readers: 5,7, 9	The method is more reliable in the small rank of patient distribution and small-scale area. However, if the PSO is improved and adopted instead of employing the classic PSO, better results may be achieved.
[77]	number of readers, interference, Power loss, coverage	an improved multi-objective brainstorming optimization algorithm (IMBSO)	50m x 50m: r50,r100,r200,c50,c100,c200	This algorithm employs the golden sine operator and the Cauchy mutation operator to improve algorithm performance. Compared with the multi-objective particle swarm optimization algorithm, multi-objective Firefly algorithm and multi-objective brainstorming algorithm, this algorithm can maximize tag coverage with the minimum number of readers while reducing reader conflicts.

where P_b as in Formula 5 is the power of the backscattered signal transmitted by the tag, dependent on the tag's reflection coefficient and its received power P_t:

$$P_b = \left(\Gamma_{tag}\right)^2 P_t \tag{5}$$

For any given tag, if there exists a readerr_1 such that $PT_{r1,t} \geq T_t$, and also a reader r_2 such that $PT_{t,r2} \geq T_r$, the tag t can be considered covered by the reader, as shown in Formula 6. Here, T_t and T_r represent the thresholds for the tag and the reader, respectively. $PT_{r1,t}$ denotes the power received by tag t from reader r_1, while $PT_{t,r2}$ signifies the power received by reader r_2 from tag t through the backscattered signal.

$$P_t\,[dBm] = P_1[dBm] + G_r[dBi] + G_t[dBi] - L[dB] \tag{6}$$

Formula 7 is the mathematical expression for tag coverage.

$$f_c = \sum_{t\in TS}^{max} Cv\left(t\right)/N_t \cdot 100\% \tag{7}$$

B. INTERFERENCE

When readers are widely dispersed throughout an RFID network, there may be instances where a tag is simultaneously within the reading range of many readers. These readers are currently attempting to connect with it simultaneously. However, because of the tag's limited functionality, it is unable to distinguish between radio frequency signals from various readers, unable to respond to the reader's identification request, and even able to cause signal interference that causes the tag's information to be lost, which is called interference. The mathematical expression is as shown in Formula 8 where M is the total number of readers. r_i is the reading range of the i-th reader, R_i is the coordinates of the i-th reader.

$$f_I = \sum_{i=1}^{M-1}\sum_{j=i+1}^{M}\left(r_i + r_j\right) - \left(dist\left(R_i, R_j\right)\right) \tag{8}$$

Additionally, another definition of interference is Formula 9. It is calculated as the summation of interference values at each tag [67].

$$f_I = \sum\nolimits_{t\epsilon TS}\sum\nolimits_{r\epsilon RS} P_{r,t} - max\left(P_{r,t}\right), P_{r,t} \geq T_r \tag{9}$$

C. ECONOMIC BENEFIT

Economic benefit is a crucial indicator in the planning of an RFID network. The economic benefit increases with reader proximity to the tag-intensive area. Formula 10 is the mathematical expression for economic benefit.

$$f_E = \sum_{k=1}^{M}\left(dist\left(R_k - Center_k\right)\right) \tag{10}$$

The number of readers and antennas are also being used as one of the evaluation indicators of economic benefits. Minimizing the number of readers or antennas without compromising coverage is an important optimization strategy [67], [68]. This helps reduce system construction and maintenance costs and make the RFID network more economical.

D. LOAD BALANCE

The number of tags given to each reader should be as equal as possible when constructing an RFID network, which called load balancing [68]. Otherwise, assigning too many tags to a single reader might decrease system performance overall, interfere with signals, and use up more energy from both the reader and the tags. Formula 11 is the mathematical expression for load balance.

$$f_L = \prod_{k=1}^{M}\frac{1}{C_k} \tag{11}$$

E. DELAY

Delay commonly denotes the period starting from the moment an RFID tag initiates a request to the point when the system receives and promptly responds. The duration of this interval significantly influences the system's responsiveness and the immediacy of data transmission. Formula 12 is the expression for delay [69].

$$Delay = T_{tans} - T_{rev} \tag{12}$$

F. POWER LOSS

Power loss is a key indicator in RFID networks, which measures the energy consumed by the reader when transmitting radio frequency signals [68]. The optimization of this indicator is to reduce the energy consumption of the reader as much as possible while maintaining communication reliability. In practical applications, effective management and optimization of power loss is crucial to building an efficient and reliable RFID network.

G. POWER

The total power can be estimated by calculating the radius of all readers within the RFID network [70]. From this definition, the number of readers is directly proportional to the total power. As the number of readers increases, the total power must increase. Therefore, this performance metric can be measured by the number of readers.

V. APPLICATION OF ALGORITHMS IN RNP

This section reviews and analyzes the current literature on RFID network planning based on swarm intelligence optimization algorithms and summarizes the innovations and shortcomings of each literature.

To ensure the research quality, the Scopus database was selected, and the keyword was set as RFID network planning + algorithm, with a total of 199 works of literature. In order to find the latest research progress in this field, the period was set as 2019-2022, with a total of 56 literatures. In order to improve the accuracy and effectiveness of the analysis, the retrieved papers were manually checked and filtered. The following representative literatures were listed for analysis, as shown in TABLE 7, to explore how swarm intelligence algorithms can be used to optimize RFID network layout, antenna parameter configuration, frequency planning and other key issues to meet the needs of different fields for efficient performance of RFID systems.

- **Optimization objectives:** All works of literature have chosen coverage as one of the optimization objectives or even the only optimization objective. It is evident that coverage is the most important objective and needs to be considered during network planning. The indicator of interference is also considered by most literature, where there are not only reader conflicts but also tag conflicts. In addition to the four typical optimization objectives of coverage, interference, economic benefit and load balancing, some literature also considers the number of antennas and positioning accuracy, expanding the optimization dimension, and making the optimization more comprehensive.
- **Experimental scenarios:** Most remain in small-scale simulation scenarios and cannot cope with large-scale actual projects.
- **Algorithms**: In [76] the classic PSO algorithm is directly used, lacking innovation. The other literature uses hybrid algorithms or improved classic algorithms to improve the search capabilities of the algorithm, which can provide ideas for future work.
- **Optimization model**: In [67], [73], and [75] a weighted method is used to transform multiple objectives into one objective. The advantage of the method is simple and easy to understand. The disadvantage is that the selection of weight coefficients is very subjective, resulting in the optimization results not being objective enough. Moreover, Simple linear weighting may not reflect the complex relationships between targets. In [74], the Pareto method is used to optimize multiple objectives simultaneously. It provides the optimal solution set for RFID network planning so that decision-makers can choose the optimal solution according to their needs.

VI. LIMITATIONS

This section examines the primary constraints associated with the deployment of smart factory technologies, such as the intricacy of diverse environments, the rigorous characteristics of optimization algorithms, and the absence of extensive validation in real-world scenarios.

- **Complex heterogeneous environment**: Smart factories usually contain different technologies, communication protocols and hardware devices [78]. The above factors need to be taken into consideration when planning the network to achieve normal data communication and ensure network interconnection.
- **High algorithm complexity**: Although the swarm intelligence optimization algorithm shows a good effect in RFID network planning, its complexity may bring challenges to actual engineering implementation. Especially in large-scale smart factories, involving huge data, large-scale tags and readers, a larger population is required for algorithm iteration [79], and more computing resources are required for network planning.
- **Insufficient verification in actual projects**: RFID network planning based on swarm intelligence optimization algorithms has rarely been verified on a large scale in actual projects. Most of them are ideal experimental environments and small-scale projects. From theoretical models to large-scale practical implementation, there are still great challenges.

VII. CONCLUSION AND FUTURE DIRECTIONS

In the context of Made in China 2025, RFID serving as a fundamental approach for data collection and monitoring, offers essential technical backing for the achievement of intelligent manufacturing and the establishment of intelligent factories. This review comprehensively introduces the principle of RFID technology and its current application in various fields. Attention is drawn to the latest advancements in swarm intelligence algorithms and the potential directions for refining these algorithms. The key performance metrics of RFID networks are outlined, along with an examination of the integration of swarm intelligence algorithms in RFID network design. Through the exploration of applications and comparative assessments, it is evident that optimization algorithms rooted in swarm intelligence can significantly enhance the efficiency of RFID networks in terms of coverage, load distribution, and financial gains, while simultaneously mitigating issues related to interference and energy consumption.

As smart manufacturing continues to evolve, intelligent optimization algorithms will continue to play an important role in supporting the construction and optimization of RFID in smart factories. Future research should direct its attention towards the following areas:

- Emphasis should be placed on the selection of equipment, communication protocols, and data formats, as well as delving into the standardization efforts within smart factories.
- Novel algorithms need to be formulated to enhance search functionalities and minimize intricacies, thereby boosting algorithm flexibility.
- Further implementation of RFID planning in authentic smart factory settings and evaluation of algorithm efficacy through engineering experiments are warranted.

It is hoped that this review will provide researchers and practitioners with insight and guidance on smart factory RFID network planning.

REFERENCES

[1] X. Ying, "Architecture and practice of intelligent factory based on IoT thinking," *Instrum. Users*, vol. 27, no. 8, pp. 99–105, Aug. 2020.

[2] E. Elbasani, P. Siriporn, and J. S. Choi, "A survey on RFID in industry 4.0," in *Internet of Things for Industry 4.0*, G. Kanagachidambaresan, R. Anand, E. Balasubramanian, and V. Mahima, Eds. Cham, Switzerland: Springer, 2020, pp. 1–16.

[3] J. Feng, F. Li, C. Xu, and R. Y. Zhong, "Data-driven analysis for RFID-enabled smart factory: A case study," *IEEE Trans. Syst., Man, Cybern., Syst.*, vol. 50, no. 1, pp. 81–88, Jan. 2020.

[4] T. Kalsoom, N. Ramzan, and S. Ahmed, "Societal impact of IoT-lead smart factory in the context of industry 4.0," in *Proc. Int. Conf. U.K.-China Emerg. Technol. (UCET)*, Glasgow, U.K., Aug. 2020, pp. 1–5.

[5] F. Galati and B. Bigliardi, "Industry 4.0: Emerging themes and future research avenues using a text mining approach," *Comput. Ind.*, vol. 109, pp. 100–113, Aug. 2019.

[6] A. Azizi, "RFID network planning," in *Applications of Artificial Intelligence Techniques in Industry 4.0*. Berlin, Germany: Springer, 2019, pp. 19–25.

[7] A. G. Dimitriou, S. Siachalou, A. Bletsas, and J. Sahalos, "Introduction of dynamic virtual force vector in particle swarm optimization for automated deployment of RFID networks," in *Proc. 13th Eur. Conf. Antennas Propag. (EuCAP)*, Krakow, Poland, Mar. 2019, pp. 1–5.

[8] A. Jaballah and A. Meddeb, "A new variant of cuckoo search algorithm with self adaptive parameters to solve complex RFID network planning problem," *Wireless Netw.*, vol. 25, no. 4, pp. 1585–1604, May 2019.

[9] X. Yang and J. Guan, "PI parameters tuning for frequency tracking control of wireless power transfer system based on improved whale optimization algorithm," *IEEE Access*, vol. 12, pp. 13055–13069, 2024.

[10] B. Ye, J. Hu, W. Zha, B. Wang, Q. Gao, G. Fang, A. K. Dwivedi, and S. Liu, "A novel magnetic spiral capsule endoscope localization method based on an improved artificial bee colony algorithm," *IEEE Sensors J.*, vol. 24, no. 2, pp. 1740–1750, Jan. 2024.

[11] E. Oztemel and S. Gursev, "Literature review of industry 4.0 and related technologies," *J. Intell. Manuf.*, vol. 31, no. 1, pp. 127–182, Jan. 2020.

[12] M. Ryalat, H. ElMoaqet, and M. AlFaouri, "Design of a smart factory based on cyber-physical systems and Internet of Things towards industry 4.0," *Appl. Sci.*, vol. 13, no. 4, pp. 2156–2175, Feb. 2023.

[13] A. Gwinner, "Implementation framework to realize the smart factory: Development of a practical framework to leverage the organizational implementation of the smart factory," M.S. thesis Dept. Eng. Tech., Jönköping Univ., Jönköping, Sweden, 2020.

[14] T. Athauda and N. Karmakar, "Chipped versus chipless RF identification: A comprehensive review," *IEEE Microw. Mag.*, vol. 20, no. 9, pp. 47–57, Sep. 2019.

[15] C. Herrojo, F. Paredes, J. Mata-Contreras, and F. Martín, "Chipless-RFID: A review and recent developments," *Sensors*, vol. 19, no. 15, p. 3385, Aug. 2019.

[16] A. Bothe, J. Bauer, and N. Aschenbruck, "RFID-assisted continuous user authentication for IoT-based smart farming," in *Proc. IEEE Int. Conf. RFID Technol. Appl. (RFID-TA)*, Pisa, Italy, Sep. 2019, pp. 505–510.

[17] F. Hu, M. Zhou, Y. Qin, Q. Zhao, Y. Xin, and G. Li, "Novel cattle farm management system based on IoT and RFID," in *Proc. 3rd Int. Conf. Comput. Sci. Manage. Technol. (ICCSMT)*, Shanghai, China, Nov. 2022, pp. 60–63.

[18] F. Mocholí Belenguer, A. Martínez-Millana, A. Mocholí Salcedo, and J. H. Arroyo Núñez, "Vehicle identification by means of radio-frequency-identification cards and magnetic loops," *IEEE Trans. Intell. Transp. Syst.*, vol. 21, no. 12, pp. 5051–5059, Dec. 2020.

[19] A. Haibi, K. Oufaska, M. Bouya, K. El Yassini, and M. Boulmalf, "Research gaps and trends in radio frequency identification: Scoping review," in *Proc. Microw. Medit. Symp. (MMS)*, Pizzo Calabro, Italy, May 2022, pp. 1–6.

[20] A. Haibi, K. Oufaska, K. E. Yassini, M. Boulmalf, and M. Bouya, "Systematic mapping study on RFID technology," *IEEE Access*, vol. 10, pp. 6363–6380, 2022.

[21] M. Hehua, "Application of passive wireless RFID asset management in warehousing of cross-border e-commerce enterprises," *J. Sensors*, vol. 2021, Dec. 2021, Art. no. 6438057.

[22] T. Zhou, D. Tang, H. Zhu, and Z. Zhang, "Multi-agent reinforcement learning for online scheduling in smart factories," *Robot. Comput.-Integr. Manuf.*, vol. 72, Dec. 2021, Art. no. 102202.

[23] Y. Liu, K. Tong, F. Mao, and J. Yang, "Research on digital production technology for traditional manufacturing enterprises based on industrial Internet of Things in 5G era," *Int. J. Adv. Manuf. Technol.*, vol. 107, no. 99, pp. 1101–1114, Mar. 2020.

[24] M. Jasprabhjit, N. Mauludin, and Y. Ray Zhong, "Smart automated guided vehicles for manufacturing in the context of industry 4.0," in *Proc. NAMRC*, 2018, pp. 1077–1086.

[25] H. L. Zhang, J. Z. Zhu, and Y. C. Dong, "A review of research on reinforcement learning forsolving combinatorial optimization problems," *J. Xinjiang Univ. (Natural Sci. Ed.)*, vol. 40, no. 2, pp. 129–141, Mar. 2023.

[26] V. Kumar and D. Kumar, "A systematic review on firefly algorithm: Past, present, and future," *Arch. Comput. Methods Eng.*, vol. 28, no. 4, pp. 3269–3291, Jun. 2021.

[27] L. Yali, W. Shuqin, C. Qianru, and W. Xiaogang, "Comparative study of several new swarm intelligence optimization algorithms," *Comput. Eng. Appl.*, vol. 56, no. 22, pp. 1–12, Apr. 2020.

[28] H. Zhi, "Research and application of swarm intelligence optimization algorithm," Ph.D. dissertation, Dept. Math., Xi'an Univ., Xi'an, China, 2020.

[29] A. Mohammadi and F. Sheikholeslam, "Intelligent optimization: Literature review and state-of-the-art algorithms (1965–2022)," *Eng. Appl. Artif. Intell.*, vol. 126, Nov. 2023, Art. no. 106959.

[30] K. Zervoudakis and S. Tsafarakis, "A mayfly optimization algorithm," *Comput. Ind. Eng.*, vol. 145, Jul. 2020, Art. no. 106559.

[31] H. A. Alsattar, A. A. Zaidan, and B. B. Zaidan, "Novel meta-heuristic bald eagle search optimisation algorithm," *Artif. Intell. Rev.*, vol. 53, no. 8, pp. 2237–2264, Mar. 2020.

[32] A. F. Peña-Delgado, H. Peraza-Vázquez, J. H. Almazán-Covarrubias, N. T. Cruz, P. M. García-Vite, A. B. Morales-Cepeda, and J. M. Ramirez-Arredondo, "A novel bio-inspired algorithm applied to selective harmonic elimination in a three-phase eleven-level inverter," *Math. Problems Eng.*, vol. 2020, Dec. 2020, Art. no. 8856040.

[33] H. Peraza-Vázquez, A. F. Peña-Delgado, G. Echavarría-Castillo, A. B. Morales-Cepeda, J. Velasco-Álvarez, and F. Ruiz-Perez, "A bio-inspired method for engineering design optimization inspired by dingoes hunting strategies," *Math. Problems Eng.*, vol. 2021, Sep. 2021, Art. no. 9107547.

[34] I. Naruei and F. Keynia, "Wild horse optimizer: A new meta-heuristic algorithm for solving engineering optimization problems," *Eng. Comput.*, vol. 38, no. S4, pp. 3025–3056, Oct. 2022.

[35] M. S. Braik, "Chameleon swarm algorithm: A bio-inspired optimizer for solving engineering design problems," *Expert Syst. Appl.*, vol. 174, Jul. 2021, Art. no. 114685.

[36] H. Carreon-Ortiz and F. Valdez, "A new mycorrhized tree optimization nature-inspired algorithm," *Soft Comput.*, vol. 26, no. 10, pp. 4797–4817, May 2022.

[37] E. Trojovská, M. Dehghani, and P. Trojovský, "Zebra optimization algorithm: A new bio-inspired optimization algorithm for solving optimization algorithm," *IEEE Access*, vol. 10, pp. 49445–49473, 2022.

[38] C. Zhong, G. Li, and Z. Meng, "Beluga whale optimization: A novel nature-inspired metaheuristic algorithm," *Knowl.-Based Syst.*, vol. 251, Sep. 2022, Art. no. 109215.

[39] W. Zhao, L. Wang, and S. Mirjalili, "Artificial hummingbird algorithm: A new bio-inspired optimizer with its engineering applications," *Comput. Methods Appl. Mech. Eng.*, vol. 388, Jan. 2022, Art. no. 114194.

[40] J. O. Agushaka, A. E. Ezugwu, and L. Abualigah, "Dwarf mongoose optimization algorithm," *Comput. Methods Appl. Mech. Eng.*, vol. 391, Mar. 2022, Art. no. 114570.

[41] A. E. Ezugwu, J. O. Agushaka, L. Abualigah, S. Mirjalili, and A. H. Gandomi, "Prairie dog optimization algorithm," *Neural Comput. Appl.*, vol. 34, no. 22, pp. 20017–20065, Nov. 2022.

[42] M. Abdel-Basset, R. Mohamed, M. Jameel, and M. Abouhawwash, "Nutcracker optimizer: A novel nature-inspired Metaheuristic algorithm for global optimization and engineering design problems," *Knowl.-Based Syst.*, vol. 262, Feb. 2023, Art. no. 110248.

[43] M. Abdel-Basset, R. Mohamed, M. Jameel, and M. Abouhawwash, "Spider wasp optimizer: A novel meta-heuristic optimization algorithm," *Artif. Intell. Rev.*, vol. 56, no. 10, pp. 11675–11738, Oct. 2023.

[44] K. Zolfi, "Gold rush optimizer: A new population-based Metaheuristic algorithm," *Oper. Res. Decisions*, vol. 33, no. 1, pp. 113–150, 2023.

[45] H. Jia, H. Rao, C. Wen, and S. Mirjalili, "Crayfish optimization algorithm," *Artif. Intell. Rev.*, vol. 56, no. S2, pp. 1919–1979, Nov. 2023.

[46] S. Cao, Q. Qian, Y. Cao, W. Li, W. Huang, and J. Liang, "A novel metaheuristic algorithm for numerical and engineering optimization problems: Piranha foraging optimization algorithm (PFOA)," *IEEE Access*, vol. 11, pp. 92505–92522, 2023.

[47] Q. Li, S.-Y. Liu, and X.-S. Yang, "Influence of initialization on the performance of metaheuristic optimizers," *Appl. Soft Comput.*, vol. 91, Jun. 2020, Art. no. 106193.

[48] T.-X. Ma, X. Duan, Y. Xu, R.-L. Wang, and X.-Y. Li, "Research on fault location in DC distribution network based on adaptive artificial bee colony slime mould algorithm," *IEEE Access*, vol. 11, pp. 62630–62638, 2023.

[49] R. Zhou, Y. Zhang, and K. He, "A novel hybrid binary whale optimization algorithm with chameleon hunting mechanism for wrapper feature selection in QSAR classification model: A drug-induced liver injury case study," *Expert Syst. Appl.*, vol. 234, Dec. 2023, Art. no. 121015.

[50] M. M. Emam, E. H. Houssein, M. A. Tolba, M. M. Zaky, and M. Hamouda Ali, "Application of modified artificial hummingbird algorithm in optimal power flow and generation capacity in power networks considering renewable energy sources," *Sci. Rep.*, vol. 13, no. 1, p. 21446, Dec. 2023.

[51] C. Zhang, H. Liu, Q. Zhou, and C. Liu, "Improved hybrid grey wolf optimization algorithm based on dimension learning-based hunting search strategy," *IEEE Access*, vol. 11, pp. 13738–13753, 2023.

[52] Y. Lu, S. Liang, H. Ouyang, S. Li, and G.-G. Wang, "Hybrid multigroup stochastic cooperative particle swarm optimization algorithm and its application to the photovoltaic parameter identification problem," *Energy Rep.*, vol. 9, pp. 4654–4681, Dec. 2023.

[53] H. Ren, H. Ren, and Z. Sun, "HSFA: A novel firefly algorithm based on a hierarchical strategy," *Knowl.-Based Syst.*, vol. 279, Nov. 2023, Art. no. 110950.

[54] J. Xue and B. Shen, "A novel swarm intelligence optimization approach: Sparrow search algorithm," *Syst. Sci. Control Eng.*, vol. 8, no. 1, pp. 22–34, Jan. 2020.

[55] L. L. Wang, L. Sun, and G. P. Ding, "Research on improved sparrow search algorithm based on multi strategy fusion," *Softw. Eng. Appl.*, vol. 11, no. 6, pp. 1182–1190, Dec. 2022.

[56] L. Y. U. Xin, M. Xiaodong, Z. Jun, and W. Zhen, "Chaos sparrow search optimization algorithm," *J. Beijing Univ. Aeronaut. Astronaut.*, vol. 47, no. 8, pp. 1712–1720, Aug. 2021.

[57] H. Li, N. Z. Zeng, and Z. D. Wang, "Multi-strategy collaborative improved sparrow search algorithm," *Appl. Res. Comput.*, vol. 40, no. 11, pp. 3269–3275, Nov. 2023.

[58] X. J. Ma, H. He, and H. W. Wang, "Maximum exponential entropy segmentation method based on improved sparrow search algorithm," *Sci. Technol. Eng.*, vol. 23, no. 16, pp. 6983–6992, Jun. 2023.

[59] V. A. Zasov and K. A. Busargina, "Possibilities of population algorithm for searching by swarm of fireflies in multiextremal optimization problems under interference conditions," in *Proc. 25th Int. Conf. Digit. Signal Process. its Appl. (DSPA)*, Moscow, Russia, Mar. 2023, pp. 1–5.

[60] J. Li, X. Wei, B. Li, and Z. Zeng, "A survey on firefly algorithms," *Neurocomputing*, vol. 500, pp. 662–678, Aug. 2022.

[61] F. Li, X. Fan, and Z. Hou, "A firefly algorithm with self-adaptive population size for global path planning of mobile robot," *IEEE Access*, vol. 8, pp. 168951–168964, 2020.

[62] M. M. Hamdi, L. Audah, and S. A. Rashid, "Data dissemination in VANETs using clustering and probabilistic forwarding based on adaptive jumping multi-objective firefly optimization," *IEEE Access*, vol. 10, pp. 14624–14642, 2022.

[63] J. Zhao, W. Chen, J. Ye, H. Wang, H. Sun, and I. Lee, "Firefly algorithm based on level-based attracting and variable step size," *IEEE Access*, vol. 8, pp. 58700–58716, 2020.

[64] G. D. Singh, M. Prateek, S. Kumar, M. Verma, D. Singh, and H.-N. Lee, "Hybrid genetic firefly algorithm-based routing protocol for VANETs," *IEEE Access*, vol. 10, pp. 9142–9151, 2022.

[65] N. Donthu, S. Kumar, D. Mukherjee, N. Pandey, and W. M. Lim, "How to conduct a bibliometric analysis: An overview and guidelines," *J. Bus. Res.*, vol. 133, pp. 285–296, Sep. 2021.

[66] Y. Cao, J. Liu, and Z. Xu, "A hybrid particle swarm optimization algorithm for RFID network planning," *Soft Comput.*, vol. 25, no. 7, pp. 5747–5761, Apr. 2021.

[67] M. Maimouni, B. A. El Majd, and M. Bouya, "RFID network planning using a new hybrid ANNs-based approach," *Connection Sci.*, vol. 34, no. 1, pp. 2265–2290, Dec. 2022.

[68] E. G. Zahran, A. A. Arafa, H. I. Saleh, and M. I. Dessouky, "A self learned invasive weed-mixed biogeography based optimization algorithm for RFID network planning," *Wireless Netw.*, vol. 26, pp. 4109–4127, Aug. 2020.

[69] M. T. Pandian, K. Chouhan, B. M. Kumar, J. K. Dash, N. Z. Jhanjhi, A. O. Ibrahim, and A. W. Abulfaraj, "Improving efficiency of large RFID networks using a clustered method: A comparative analysis," *Electronics*, vol. 11, no. 18, p. 2968, Sep. 2022.

[70] S. Q. Mohammed, M. N. Abdullah, and A. S. Al-Araji, "Hybrid swarm intelligence algorithm design for optimizing RFID-NP," *Wireless Pers. Commun.*, vol. 131, no. 4, pp. 1–31, Aug. 2023.

[71] L. Ma, X. Wang, M. Huang, Z. Lin, L. Tian, and H. Chen, "Two-level master–slave RFID networks planning via hybrid multiobjective artificial bee colony optimizer," *IEEE Trans. Syst., Man, Cybern., Syst.*, vol. 49, no. 5, pp. 861–880, May 2019.

[72] W. Shi, W. Wang, Y. Yu, S. Zhang, Y. Cao, S. Yan, and J. Gao, "Optimal deployment of phased array antennas for RFID network planning based on an improved chicken swarm optimization," *IEEE Internet Things J.*, vol. 8, no. 19, pp. 14572–14588, Oct. 2021.

[73] J. Zhang, J. Zheng, X. Xie, Z. Lin, and H. Li, "Mayfly sparrow search hybrid algorithm for RFID network planning," *IEEE Sensors J.*, vol. 22, no. 16, pp. 16673–16686, Aug. 2022.

[74] X. Xie, J. Zheng, M. Feng, S. He, and Z. Lin, "Multi-objective mayfly optimization algorithm based on dimensional swap variation for RFID network planning," *IEEE Sensors J.*, vol. 22, no. 7, pp. 7311–7323, Apr. 2022.

[75] L. WenCong and Z. JiaLi, "RFID reader antenna optimal deployment based on improved elephant herding algorithm," in *Proc. IEEE Int. Conf. Consum. Electron. Comput. Eng. (ICCECE)*, Guangzhou, China, Jan. 2021, pp. 348–352.

[76] R. Musadaq, G. Cansever, and A. H. Radie, "Real-time monitoring patients using RFID network planning scheme," in *Proc. 4th Int. Iraqi Conf. Eng. Technol. Their Appl. (IICETA)*, Najaf, Iraq, Sep. 2021, pp. 184–189.

[77] J. Zheng, Z. Lin, and X. Xie, "Improved multi-objective brain storm optimization algorithm for RFID network planning," *Wireless Netw.*, vol. 30, no. 2, pp. 1055–1068, Feb. 2024.

[78] R. Y. Zhong, G. D. Putnik, and S. T. Newman, "A heterogeneous data analytics framework for RFID-enabled factories," *IEEE Trans. Syst., Man, Cybern., Syst.*, vol. 51, no. 9, pp. 5567–5576, Sep. 2021.

[79] Y. Gao, "Research on nonlinear time series hybrid prediction model based on swarm intelligence optimization," Ph.D. dissertation, Dept. Statist., Shandong Univ. Finance Econ., Shandong, China, 2022.

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