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Swarm Intelligence Algorithms Inspired by Nature: A Review

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Abstract

This work presents a comprehensive overview of nature-inspired optimization algorithms their components, classifications, and applications in various domains. The paper focuses on the importance of basic technique in swarm optimization algorithms such as: Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Whale Optimization Algorithm (WOA), Artificial Bee Colony Algorithm (ABC), Salp Swarm Algorithm (SSA), Firefly Algorithm (FA), Grasshopper Optimization Algorithm (GOA), and other Swarm Intelligence Algorithms in solving complex problems. This study shows the classification of living organisms in order to classify and explore algorithms inspired by nature, and presents related works from (2020) to (2025), related to algorithms inspired by nature.

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1. Introduction

Swarm Intelligence is considered as one of social-behavior monitoring concepts inspired for organisms living in groups, such as fish swarms and ant colonies. Thus researcher are interest in understanding the inner mechanisms of grouping behavior through building models that simulates this phenomena (Wang et al., 2025). Swarm Intelligence (SI) is one of the main classes of algorithms inspired by nature that seeks to simulate nature processes and optimize multi-objectives, such as minimizing cost and power, and at the same time maximizing performance ,efficiency, and sustainability in solving complex problems that cannot be solved it with traditional techniques, it is considered as organic combinations between evolution, computing, Artificial Neural Networks, and fuzzy systems (Tang et al., 2021) (Yang, 2020; Balamurugan et al., 2021) . They are benefit from biological, chemical, and physical patterns , so increasing used of that algorithms in Artificial learning, data mining and image processing domains reflect the importance in finding optimal solutions adaptable with different environments(Balamurugan et al., 2021). Nature-inspired algorithms include multiple basic classes: Swarm Intelligence ,physics role based, natural evolution, algorithms inspired by human behavior, Wang and Beni proposed the term “Swarm Intelligence” in the context of learning robotics cellular systems, recently considered as one of subcategories for swarm intelligence (Balamurugan et al., 2021). SI have been used in wide scale applications; especially in optimization problems, and scaled to be used in different engineering and scientific domains. The main feature of SI is based on “Stigmergy”, that means communication between agent through surrounding environments (Jiwane, 2025).

Optimization problems are identified by presence of constraint, objective-function, and decision variables. Optimization algorithms are classified into inevitability and random; the first needs wide information about the problem, where as the other is more suitable for non-linear, complex problem especially when dealing with it as a "black box". Metaheuristics algorithms is one of the best optimization-random methods, it generates primary random solutions then updating it till accessing to the suitable solution. No-Free-Lunch means there is no Metaheuristics algorithm achieves the optimal solution in every type of problems, that is require to develop new algorithms with higher convergency-speed and best ability for finding the optimal solutions(Amiri et al., 2024). Apart from multiple succusses of these algorithms, these are some drawbacks(Pastor Reglos Arguelles Jr & Maka Jish- Kariani, 2023):

a) There are many research challenges associate with its effective-performance, scalability and on different the type of problems.
b) The increases number of proposed algorithms in recent years presents issues in classifications and approach-comparisons between them.

The first part of this study shows classification and component of Nature-Inspired Optimization Algorithms (NIOAs). The second part of this work showed its subcategory "Swarm Intelligence", challenging, applications, and in the last part of this work discusses previous work related to Optimization Swarm Intelligence algorithms inspired by Nature.

Related works

In 2020, Yang addressed Natural-Inspired Optimization Algorithms and their use in solving complex and non-linear problems in engineering and science, these have been classified into two primary classes: procedure based like Genetic Algorithm, and equation-based like PSO, FA, DE and BA; Yang classified the solution mechanisms into five classes: Gradient Guided Moves, Random Permutation, Direction Based Perturbations, Isotropic Random Walks and Long Tailed Random Walkes. Although of their successes, Yang identified opened challenges in that research, presented as: absence united mathematic framework , difficulties in parameter tuning of each algorithm, determine the useful type of benchmarks ,and in special circumstance are there free lunches (multi-objective optimization)?, the other open challenges faced him was as multiple different metrices have been used, it was difficult to choose the suited metrices for fairly comparison to all algorithms and to design a unified-framework for comparisons. The latest open challenge that is how can scalable the algorithm scale that works well in small problems to solve large problems effectively. That provides critical analysis for fundamental research concerning Nature-Inspired Algorithms, and clarifying a pathway for limitation points. Limitations of this study, are; big parts of challenges did not present direct practical solutions, and depending on reviews of previous researches without producing new applicable experiences, as well as the difficulty of designing unified-framework for algorithms diverse(Yang, 2020).Ibraheem & Saleh (2020), addressed new strategy for balancing loads in cloud computing through Bats algorithm, it is one of swarm intelligence algorithms that simulates bat's behavior in using echo to determine prey position and avoiding obstacles. To enhance the effectiveness of model, researchers used Naïve Bayes as a tool to classify the virtual machines into three classes: light load, balanced and heavy load, that helped in making more accurate decisions. Results of "Load Balancing Bat Algorithm (LBBA)" achieved better performance in comparisons with the traditional algorithms such as Dynamic Load Balancing (DLB), thus is became it minimizes response time and complete time in to 50%, as well as enhancing the quality of services (QoS). Limitations of this study; the model was based on assumptions of independent tasks and non-preemptive, also the need to make more experiments in huge cloud environments so as to ensure its scalability and adaptability(Ibrahim & Saleh, 2020).Khaleel (2021) explored an innovative system for colored image compression efficiently. Swarm intelligence techniques have been used in clustering operations effectively, where used Particle Swarm Optimization (PSO) and Grey Wolf Optimization (GWO), these were optimized by hybridize with Fuzzy Logic through Gustafson Kessel fuzzy. Thus, two new hybrids methods resulted: fuzzy particle swarm (FPSO) and fuzzy grey wolf optimizer (FGWO). Furthermore, Khaleel used Huffman in coding data compression for achieving effective lossless-compression with high quality. Findings have been shown that new hybrid technique (FGWO with Huffman) is out-performed other techniques, thus, achieving high comparison rate and excellent image quality according to quality metrices. Strength points of this research are the integration between SI and Fuzzy Logic and dependency on mathematical methodology for comparison using known image-comparison metrices. The limitations are the tests that centered on limited images and data sets (and did not apply on huge images, and also the research did not explain the practical aspects like performance-speed, and resource consuming to make a comparison with other solution in AI domain (Mosul University & Khaleel, 2021a).Luis M. Torres-Trevino (2021), presented a comprehensive review for natural inspired algorithms, he proposed a classification based on biological kingdoms (animals, plants, fungi, bacteria, Protista, and viruses). The work included tables and detailed lists for algorithms most popular in each category. The main contribution of his work is the establishment of clear, hierarchical, classification system that enables researchers understand each algorithm, and determine its category in term of inspiration source and practical behavior. The classification provided a systematical reference for more than 100 algorithms that enabling a comparison of innovation trends and algorithms correlating with real application. The key strength of this work is its organization-comprehensive and accuracy in cataloguing, and adopt clear biological classification to make easy for researchers back to it. On the other side did not discuss in details the practical performance of algorithms, and did not provide a comparison between algorithms in term of computational power, or responsiveness with real world problems. Moreover, the classification was only for basic algorithms without touching upon hybrids, or modern derivatives (Torres-Treviño, 2021).Rebika Rai et al (2022) addressed an extensive study and review for the latest nature-inspired algorithms (2019-2021) in techniques of optimization domains for identifying multilevel thresholding (MLT) for image segmentation, and finding a group of thresholding that verifies the best image segmentations. Theoretical and practical challenges have been analyzed by developing image segmentation models using those algorithms. Basic contribution of this review, provided comprehensive cognitive reference for modern, natural, optimization algorithms such as (PSO, DE, ABC, GWE, HHO, and others) this review also showed using image segmentation according to multi-threshold, with highlighting strengths of each algorithm and its limitations in practical application based on segmentation-quality, performance-speed, and the ability on processing complex images. The strength of this study lies in its comprehensiveness and analysis of most modern algorithms in methodological way, supporting results with newest references and clarifying the connection of theoretical applications with real problems in industrial and medical images. This study provided a strong starting for new researchers in this domain, where challenges and clear development points are viewed. Although of the wide coverage of this study , it still lacks the integration pilot assessments on huge real image sets , and some hybrid algorithms were not systematically detailed in term of performance, or comparative measurements, as well as it did not address precise differences in depth between applications of medical images and other industrial applications (Rai et al., 2022).Yi Zhou et al (2023) systematically reviewed and bibliometric analyzed application of Inspired-Natural Optimization algorithms in resource managements, power, data and products in modern institution. The researchers relied on reviewing the literature and determined the research trends in using these algorithms. Results showed that these algorithms achieve clear improvements in minimizing cost and maximizing the efficiency of power and resources management in institutions. Genetic Algorithm is therefore identified as the most popular and distinctive in administrative applications. This study also presented cognitive maps for people with research interests. This research is characterized by comprehensive it, thus, combines between details bibliometric analysis and systematic reviews for most important modern administrative applications. It is also prominent in monitoring global research trends and connecting programming solutions with practical institution requirements. Despite that, this study did not present new algorithm or an innovative application, whereas the quality of bibliometric analysis depends on database-scope and keywords that researchers use, thus any omission in this regard may affect the comprehensiveness of results (Zhou et al., 2023).Guo-Yin Wang et al (2023) addressed a comprehensive review focusing on Swarm Intelligence evolution domain, from biologically inspired single-community models to hybrid models combining human and machine. The study relied on dividing research structure into three layers: biological-models layer (including single-community and multi-communities) and hybrid models layer (human-machine). It highlights that the current intelligence swarm development is moving toward combining human-intelligence with artificial intelligence algorithms to produce more efficient and flexible systems for resolving complex problems which are difficult for biological or computational systems to handle individually. The strength of this study, is that it presented systematical hierarchical structure explaining development of swarm intelligence from comprehensive perspective and focusing on fundamental shifts in the domain. Also, it deeply viewed different models and discussed strength and limitation of each of it. On the other side there is a lack of studies that systematically analyzed the relationship between biological and hybrid models, these making some results theoretical and lack to practical application in wide ranges(Wang et al., 2023).Elvis Han Cui et al (2024) presented a research paper exploring nature-inspired metaheuristic algorithms that are considered as efficient tools for processing complex optimization issues. The objective of this paper is to show the efficiency of these algorithms in statistical, bioinformatics and psychology domains, as well focusing on "competitive swarm optimizer with mutating agents (CSO-MA)". CSO-MA have been applied on different designs and estimation problems such as statistical models in bioinformatics models, physiological & educational models, medicine & statistical models … etc. Performance comparison have been done for CSO-MA with PSO, where results indicate that CSO-MA achieved the best solutions in most cases, especially in statistical and bioinformatic domain. Strength of this research, is that it showed new practical experiences for modern algorithms and proving it succeed across wide range of real-world problems as well as providing practical evidence of its diversity and flexibility. Despite of that, these algorithms are still rarely used in some practical fields, it need for wider applicable studies and systematical comparison on big data and real industrial problems or against other more diverse modern algorithms instead of focusing on proving one superior algorithm (Cui et al., 2024).Shen Si-Ma et al (2025) submitted a study exploring the "efficient maximum iterations for swarm intelligence algorithms", showing that there is a shortage in large-scale studies that comparing performance of algorithms based on different issue types. In order to achieve that; study made a large-scale comparison for 123 of common swarm algorithms, and tested it base on three sets of standard test functions (CEC benchmarks). Results of this research showed that the maximum number of effective iterations are based on problem type (dimensions, research space, and complexity), which in the simple problems (low-scale dimensions, large research space) the number of effective iterations reached up to 300 iterates, while in other problems, they were leaning to benefit from the maximum number of iterations. Strength of that research is the large scope (123 algorithm) and the focus on a very practical problem (efficiency of computing), which is mostly overlocked in research that focuses only on solution accuracy. The limitations of this study are: results are still closely related with using test functions (CEC). Despite of that functions being standard, the generalization of numbers (such as 300 iteration) on all real-world problems may not be accurate; because real-world problems may have different features (noise or dynamic) did not cover by test functions (Si-Ma et al., 2025).

2. Nature-inspired optimization algorithms (NIOA)

NIOAs utilize phenomena inspired from nature, like bio-systems, behavior of animals, physical and chemical systems, and used in optimization issues resolution within engineering and AI domains. Most of these algorithms have been built on a general framework including symmetric stages: determine and generate primary assembly (initial assembly), evaluate solutions using fitness function, generate new generation from solutions according to natural or wilderness behavior's life changing simulations, then terminate the operation depending on specific stop condition. The essential differences between these algorithms is the method of generating next new assembly generation (Zakeri et al., 2022). Process of looking for optimal solution that achieves a group of objectives combined with the system's requirements or restrictions, is called "Optimization" (Korani & Mouhoub, 2021). Optimization algorithms are divided into two basic types: exact algorithms that guarantee finding the optimal solution; computationally these are expensive and mostly not useful for large and complex problems, the other algorithm type is called approximate algorithms this type are not always guarantee the optimal solution but it make a balancing between the consuming time and quality of solution, Nature-Inspired (NI) algorithms is a powerful subcategory from this type (Korani & Mouhoub, 2021).

The applications of NIOAs are not limited on optimization problems only, it extends to different domains like dynamic optimization, feature selection in huge data ,deep learning, internet of things (IOT), and image processing(Torres-Treviño, 2021).

NIOAs is classified into five main classes according to the source of inspiration: Natural Evolution-based, like Genetic Algorithms that inspired from Darwin's theory in natural-selection, Swarm Intelligence-based, like PSO (Particle Swarm Optimization), Biological-Based like FPA (Flower Pollination Algorithm), Science-Based like WCA (Water Cycle Algorithm), and others algorithms that are derived from different natural phenomena, the classification is illustrates in figure(1), and table (1) (Sachan et al., 2021).

Table 1. Classification of Nature-Inspired Optimization Algorithms (NIOAs)(Sachan et al., 2021)

Category	**Inspiration Source**	**Representative Algorithms**	**Main Application Domains**
Natural Evolution-Based	Darwin's theory in natural-selection	Genetic Algorithm (GA), Environmental Adaption Method	Optimization, like estimation of software effort, cloud computing scheduling, test case generation.
Swarm Intelligence-Based	Inspired by the behavior of collective organisms	Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), Firefly Algorithm (FA)	Selection problem of train routing, cloud resource allocation, traveling salesman problem, feature selection
Biological-Based	Patterns of social behavior in biological systems	Flower Pollination Algorithm (FPA), Shuffled Frog Leaping Algorithm (SFLA),	Scheduling of grid task, Sudoku puzzle solving
Science-Based	Concepts of Scientifics	Water Cycle Algorithm (WCA), Gravitational Search Algorithm (GSA)	Water distribution system, Assignment problem of routing and wavelength in optical networks
Other Algorithms	Inspired by other phenomena	Teaching–Learning-Based Optimization (TLBO), Jaya algorithm	Problem of data clustering, Problem of Tea Category Identification

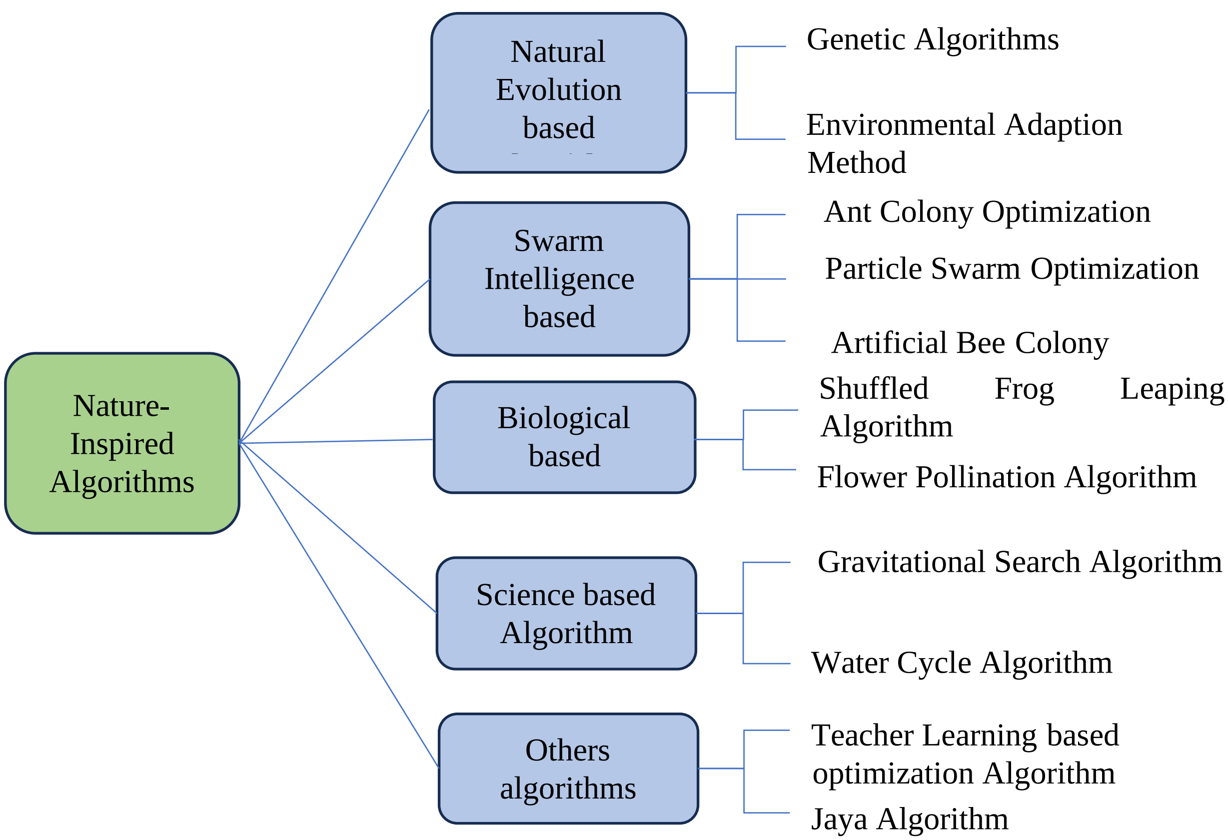

Figure 1. Classification of nature-inspired algorithms (Sachan et al., 2021)

2.1. Components of Nature Inspired Optimization Algorithm

Despite the multiplicity of natural inspired optimization algorithms, but they share in general concepts applied in different ways (Kumar et al., 2023):

- **Exploration**: searching in new regions not visited before in searching-space to avoiding non-optimal solutions.
- **Exploitation**: enhancing solutions using current knowledge and focusing on the best regions around known-solutions.
- **Encoding**: solutions implementation in formulae to suite issues such as binary chains, arranged or un-arranged groups, or matrices.
- **Generate new solutions**: done randomly or by using running factors depending on the current solutions.
- **Elitism**: saving current solutions and preventing its loss through repeats.
- **Stopping criteria**: identify when must be terminate searching operation, like number of repeats or differences in solution quality.
- **Results Interpretation**: because of the randomly nature for the most algorithms, running is repeated and choosing the best solutions.

3. Swarm intelligence

Swarm Intelligence is one of the artificial intelligent branches that cares about design and implements multiple agents systems inspired from insects and behavior of social animals like ants, bees, fishes, birds and bats. It is characterized by the ability to deal with complex and non-linear problem resolution in high efficiency and flexibility that adapts with changes. This is dependent on two basic features: self-organization and division of Laboure. Self-organization take place without need to central coordinating authority, and it achieves an effective coordination between agents, performance speed and ability to fault tolerance. Division of Laboure refers to parallel different tasks implementations of agents that increase the efficiency of systems(Nayyar et al., 2018). SI dependent on self-distribution, self-organization, and local-communication among individuals(Mosul University & Khaleel, 2021b).

Optimization methods based on swarm intelligence are growing in popularity as a means of resolving present real-world problems. Inspired by the coordinated behaviors of social insects and other animal societies, Swarm Intelligence (SI) has proven to be highly effective at solving challenging optimization problems (Jiwane, 2025).

There are several challenges facing SI like: (Zangana et al., 2024)

- Scalability:SI algorithms meet challenges in scalability when it works with large-scale problems that lead to increased computational complexity and time of converge.
- Robustness and Adaptability: SI algorithms suffer from difficulties in dynamic and unconfirmed environments, that is requiring developing mechanisms to adjust transactions and adaptive learning.
- Exploration and Exploitation Trade-off: there is a challenge in achieving balancing between Exploration and Exploitation to ensuring effective navigation in space of searching and access to high quality solutions.

SI considered as a one of main subcategory of population-based natural-inspired class of algorithms (working on groups of solutions at the same time) (Korani & Mouhoub, 2021).

3.1 SI based techniques

There are many representativeness for swarm algorithms and most common are:

- **Ant Colony Optimization (ACO)**: depended on observing ant’s behavior in searching for food and how reinforcement of good pathways by using pheromones. This algorithm is the most successful method in solving pathways issues. It uses the principle of Positive feedback to direct ants to the best solution. More than one version was developed like MAX-MIN Ant system for solving the different Optimization issues. (Tang et al., 2021)
- **Particle Swarm Optimization (PSO)**: inspired idea from movement of birds and fishes swarms, which every particle location is determined by the best particle location and the best location found from the swarm. Kennedy and Eberhart proposed PSO based on this hypothesis(Sachan et al., 2021).

- **Whale Optimization Algorithm (WOA)**: inspired from unique feeding behavior for Humpback whales, especially "Bubbles Net" technique that utilized to hunt its prey. WOA developed to be a stronger tool for solving complex, stochastic optimization issues (Okwu & Tartibu, 2021).
- **Artificial Bee Colony Algorithm (ABC)**: simulates the bees-behaviors from looking for food resources. Karaboga suggested it in the first time, then Akaya, Karaboga, & Basturk are developed it. The algorithm model consists of three bees-groups: worker bees, observer bees, and scout bees, bees are distributed between these groups where worker bees are those searching for food resources (solution), information about nectar quantity (objective function value), and food locations are sharing with observer bees, that they choose one of resources according to probability of nectar quality. Scout bees are the bees that left his food resources and make random looking for new food resources(Khaleel, 2014).
- **Salp Swarm Algorithm (SSA)**: inspired from behaviors of Salp in oceans, moving in a swarm as a chain looking for food. It proposed for solving optimizing issues ,especially in feature selection in large scale datasets(Rostami et al., 2021; Zhang et al., 2023).
- **Firefly Algorithm (FA)**: simulates the behavior of fireflies in attracting each other with light, it is characterized by the ability of dealing with multi-peak issues due to its non-linear nature (Yang, 2023).
- **Grasshopper Optimization Algorithm (GOA)**: simulates the grasshopper movement, it makes a combination between social interactions and physical power like wind and gravity to compute the new location(Warnakulasooriya & Segev, 2025).

Other Swarm Intelligence Algorithms: include inspired algorithms from other behavior birds, insects, animals groups and others. These algorithms seek to minimize the number of transaction, simplify procedures, speeding the performance especially in optimal cases with large-scale and multi-objectives(Tang et al., 2021).

Table 2. A summary of Swarm intelligence algorithms

Algorithm	**Inspiration & Key Mechanism**	**Strength & Limitation**
Ant Colony Optimization (ACO)	Inspired from ant's behavior in searching for food and how reinforcement good pathways by using pheromones that secreted by ants to find the path(Tang et al., 2021).	**Strength:** finding solutions for difficult optimization problems using tree or graph (Sachan et al., 2021). **Limitation**: it needs precise selection of parameters, such as evaporation rate of pheromones, number of ants, and taking into account the scale and complexity of the problems(Abdelmoaty & Ibrahim, 2024).
Particle Swarm Optimization (PSO)	inspired idea from movement of birds and fishes swarms, which every particle location is determined by the best particle location and the best location that found from the swarm(Sachan et al., 2021).	**Strength**: easy to implement and understand, it has relatively few parameters that need to tune, rapid convergences that rapidly access to the optimal solution(Gad, 2022). **Limitation**: difficulties in determining the initial values for control parameters, inability to solve swarm scattering problem, early convergence and fall in local minima solution especially in large scale problems (Gad, 2022)
Whale Optimization Algorithm (WOA)	inspired from unique feeding behavior for Humpback whales, especially "Bubbles Net" technique that utilized to hunt its prey(Okwu & Tartibu, 2021).	**Strength**:it has a strong optimization ability in finding optimal solution, it is a strong robust algorithm and simple in implementation(Wang et al., 2022) . **Limitation**: easy to fall in local optimum instead of global optimum, easy to access to stagnation phenomenon, cannot be used in classification, dimensionally reduction or solving knapsack problems(Wang et al., 2022).

Artificial Bee Colony Algorithm (ABC)	simulates the bees-behaviors from looking for food resources(Khaleel, 2014).	**Strength**: easy to use and implement, ability to integration with other algorithms and increasing the performance of optimization issues, ability to solve different sets of optimization issues(Okwu & Tartibu, 2021). **Limitation**: it needs precise parameters tunning that's time consuming, and the need for multiple and randomly initialization processes(Okwu & Tartibu, 2021).
Salp Swarm Algorithm (SSA)	inspired from behaviors of Salp in oceans, moving in a swarm as a chain looking for food[19].	**Strength**: speed of optimization and accurate convergence, balancing in exploration and exploitation, performance stability and accuracy in result comparing with PSO and others(Zhang et al., 2023). **Limitation**: complicate computation and maximize implementation time, need for early parameters tunning, and it is not always the best for simple, single-model function(Zhang et al., 2023).
Firefly Algorithm (FA)	simulates the behavior of fireflies in attracting each other with light(Yang, 2023).	**Strength**: solving complex optimization non-linear, multi-modal problems, high flexibility; easily integrate it with optimization technology. It does not require a good initial solution(Okwu & Tartibu, 2021). **Limitation**: it includes additional control variables that needing to tune, and it requires large numbers of iterations to reach to the solution(Okwu & Tartibu, 2021).
Grasshopper Optimization Algorithm (GOA)	simulates the grasshopper movement, it makes a combination between social interactions and physical power like wind and gravity to compute the new location(Warnakulasooriya & Segev, 2025)	**Strength**: high ability in exploring research space, simplicity, robustness, flexibility, extendibility, and ability to integrate with other metaheuristic algorithms, and balancing between exploration and exploitation(Meraihi et al., 2021). **Limitation**: early convergence, lack in exploitation of research space, and it requires adjustments and tunning(Meraihi et al., 2021).

Biological classifications algorithms have been suggested depending on living-organisms kingdoms like animal, plant, bacteria, fungi and others, that's illustrated in the figure (2) (Molina et al., 2020), (Torres-Treviño, 2021):

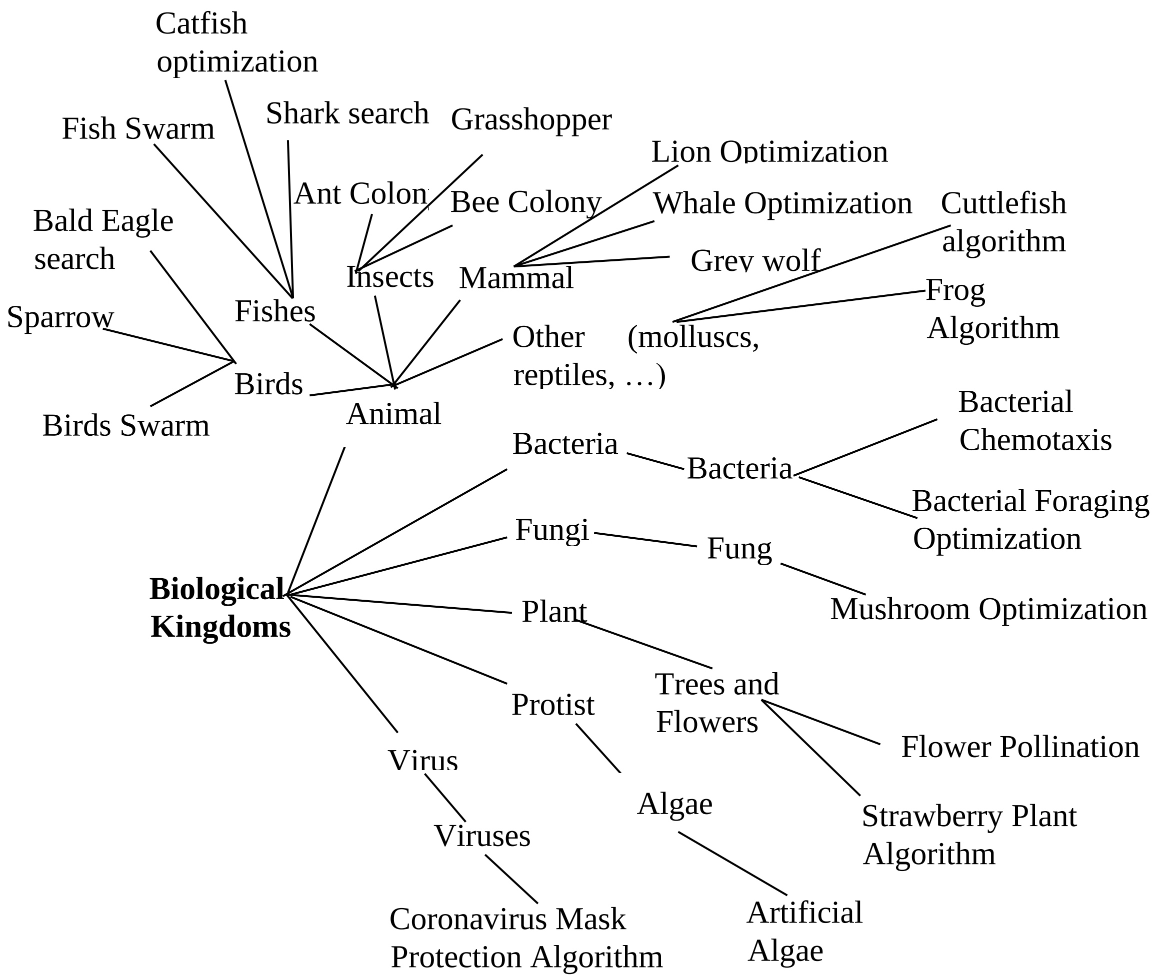

Figure 2. Biological classifications (summarized from (Molina et al., 2020), (Torres-Treviño, 2021))

Table 3. A Summary of related works of Nature-inspired optimization algorithms

Author	*Methodology*	*Results*	*Limitation*
X.-S. Yang (2020)	Classifying Nature-inspired optimization algorithms into classes for solving complex, nonlinear problems	Open challenges have been found: absence unified mathematical framework, difficulties in parameter tuning of each algorithm, determine the useful type of benchmarks, are there free lunches (multi-objective optimization, and what are suited metrices for fairly comparison to all algorithms and how designing a unified-framework for comparisons, the latest open challenge that is how can scalable the algorithm that is work well in small problems to solve large problems effectively.	There are big parts of challenges did not present direct practical solutions, and depending on reviews of previous researches without producing new applicable experiences, as well as the difficulty of designing unified-framework for algorithms diverse
Ibraheem & Saleh (2020)	Balancing load in cloud computing through “Bat algorithm” combining with Naïve Bayes as a tool for virtual machine classification.	The result of “Load Balancing Bat Algorithm (LBBA)”, achieved better performance in comparisons with traditional algorithms like Dynamic Load Balancing (DLB), minimizes response time and complete time in to 50%, enhancing the quality of services (QoS).	The model was based on assumptions of independent tasks and non-preemptive, also the need to make more experiments in huge cloud environments so as to ensure its scalability and adaptability
Khaleel (2021)	Enhancing colored image compression using (PSO), (GWO) with Gustafson Kessel fuzzy.	Two new hybrids methods are resulted: fuzzy particle swarm (FPSO) and fuzzy grey wolf optimizer (FGWO), (FGWO) algorithm presented higher performance comparing with others methods, especially in compression ratio and image quality metrices like RMSE, PNSR, that’s characterized with balancing between compression efficiency and the quality of end colored image.	The tests that centered on limited images and data sets (and did not apply on huge images, and also the research did not explain the practical aspects like performance-speed, and resource consuming to make a comparison with other solution in AI domain
Luis M. Torres-Trevino (2021)	Classifying biological kingdoms	Results have been produced that classification is contributed in organizing the increased knowledge in this domain, and highlight on most affecting algorithms like ant, particles, artificial bees, grey wolf, and whale, that is helping researchers in identifying research gaps and directing future effort effectively.	This study did not discuss in details the practical performance of algorithms, and did not provide a comparison between algorithms in term of computational power, or responsiveness with real world problems. Moreover, the classification was only for basic algorithms without touching upon hybrids, or modern derivatives

Rebika Rai et al (2022)	Using a “Aquila Optimizer (AO)”, “Arithmetic Optimization Algorithm (AOA)”, “Archimedes Optimization Algorithm (AROA)”, “Rat Swarm Optimization Algorithm (RSA)”, “Particle Swarm Optimization (PSO)”, and “Firefly Algorithm (FA)” in techniques of optimization domains for identifying multilevel thresholding (MLT) of image segmentation	Results show (AROA) superiority in segmentation accuracy and stability comparing with other, the quality-metrics of image are enhancement with increasing the numbers of thresholds.	Still lacks the integration pilot assessments on huge real image sets, and some hybrid algorithms were not systematically detailed in term of performance, or comparative measurements, as well as it did not address precise differences in depth between applications of medical images and other industrial applications
Yi Zhou et al (2023)	Development and application of “Nature-Inspired Optimization Algorithms (NIOAs)” like Genetic algorithms (GA), and “Particle Swarm Optimization (PSO)” in modern management processes.	results achieved larger efficiency, minimize costs and consumption, enhanced power consumption, decrease lost in intelligence networks and microgrids, develop advanced models for multi-resources power management, and enhancement power management system for hybrid cars. NIOAs proved its high efficiency in solving complex and difficult problems for modern managements	This study did not present new algorithm or an innovative application, whereas the quality of bibliometric analysis depends on database-scope and keywords that researchers use, thus any omission in this regard may affect the comprehensiveness of results
Guo Yin Wang et al (2023)	Hierarchical classification of Swarm Intelligence	It is useful for researchers to study the classification of Swarm Intelligence.	There is a lack of studies that systematically analyzed the relationship between biological and hybrid models, these making some results theoretical and lack to practical application in wide ranges
Elvis Han Cui et al (2024)	showing the efficiency of metaheuristic nature-inspired algorithms in statistical, bioinformatic, and psychology domains, as well focusing on “competitive swarm optimizer with mutating agents (CSO-MA)”	Results indicate that CSO-MA achieved the best solutions in most cases, especially in large-scale dimensions, the paper ensured that “nature-inspired optimization algorithms (NIOAs)”, especially CSO-MA provide a powerful effective tool for processing optimization issues in statics and biological domains.	These algorithms are still rarely used in some practical fields, it need for wider applicable studies and systematical comparison on big data and real industrial problems or against other more diverse modern algorithms instead of focusing on proving one superior algorithm

Shen Si-Ma et al (2025)	Using three main standard benchmark sets: classical sets, CEC 2019, and CEC 2022 for exploring the "efficient maximum iterations for swarm intelligence algorithms"	Results of this research showed that the maximum number of effective iterations are based on problem type, which in the simple problems, the number of effective iterations is reached to 300 iterate, while in other problems, they were leaning to benefit from the maximum number of iterations. In classic sets, large number of iterations were benefit for the most algorithms, whilst in "CEC 2019", and" CEC2022" not had benefit from more than 100 iterations. In way related with individual algorithms "Reptile search algorithm (RSA), Differential evolution (DE), and Light spectrum optimizer (LSO)" were the fastest in all three testing sets, for that, study assured there is no one optimal algorithm for all types of issues	Results are still closely related with using test functions (CEC). Despite of those functions being standard, the generalization of numbers (such as 300 iteration) on all real-world problems may not be accurate; because real-world problems may have different features (noise or dynamic) did not cover by test functions

The researcher believes that, Particle Swarm Optimization (PSO) is the most common swarm intelligence algorithms that have been used in many image applications like, enhancing color images compression, and identifying multilevel thresholding (MLT) of image segmentation, and also used in modern management processes such as, enhanced power consumption, decrease losses in intelligence networks and microgrids, and else.

Conclusion

This work addresses a comprehensive analysis of nature-inspired optimization algorithms, focusing on application, techniques and their classification. The study shows nature-inspired algorithms as a powerful optimization algorithm for solving complex, non-linear problems, and selecting the optimal features for the object from large numbers of unselected features. The challenges were there is no specific optimal algorithm for optimization problems, that made optimization algorithms depend on problem size, complexity, and problem parameters.

Future work should use more Hybrid Nature-Inspired Algorithms in every real-world optimization problem.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Ethical Approval

Ethical approval was not required for this study as it did not involve human participants, personal data.

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خوارزميات ذكاء السرب المستوحاة من الطبيعة: مراجعة

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الخلاصة: يقدم هذا العمل نظرة شاملة على خوارزميات التحسين المستوحاة من الطبيعة، ومكوناتها، وتصنيفاتها، وتطبيقاتها في مجالات مختلفة. تركز الورقة على أهمية التقنية الأساسية في خوارزميات تحسين الأسراب مثل: تحسين مستعمرة النمل (ACO)، تحسين سرب الجسيمات (PSO)، خوارزمية تحسين الحيتان (WOA)، خوارزمية مستعمرة النحل الصناعية) IBC)، خوارزمية سرب السلب (SSA)، خوارزمية اليراعة (FA)، خوارزمية تحسين الجراد (GOA)، وخوارزميات ذكاء السرب الأخرى في حل المشكلات المعقدة. تظهر هذه الدراسة تصنيف الكائنات الحية من أجل تصنيف واستكشاف خوارزميات مستوحاة من الطبيعة، وتقدم أعمالا ذات صلة من (2020) إلى (2025)، تتعلق بخوارزميات مستوحاة من الطبيعة.

الكلمات المفتاحية: خوارزميات ذكاء السرب، خوارزميات التحسين المستوحاة من الطبيعة، التصنيفات البيولوجية، تقنيات خوارزميات السرب.