Advanced AI Methods for Intelligent Data Analytics and Predictive Decision Making

Amrita Yadav[1]

[1]**Rashtriya Raksha University, Lucknow, UP**

DOI: https://doi.org/10.51583/IJLTEMAS.2026.150800076

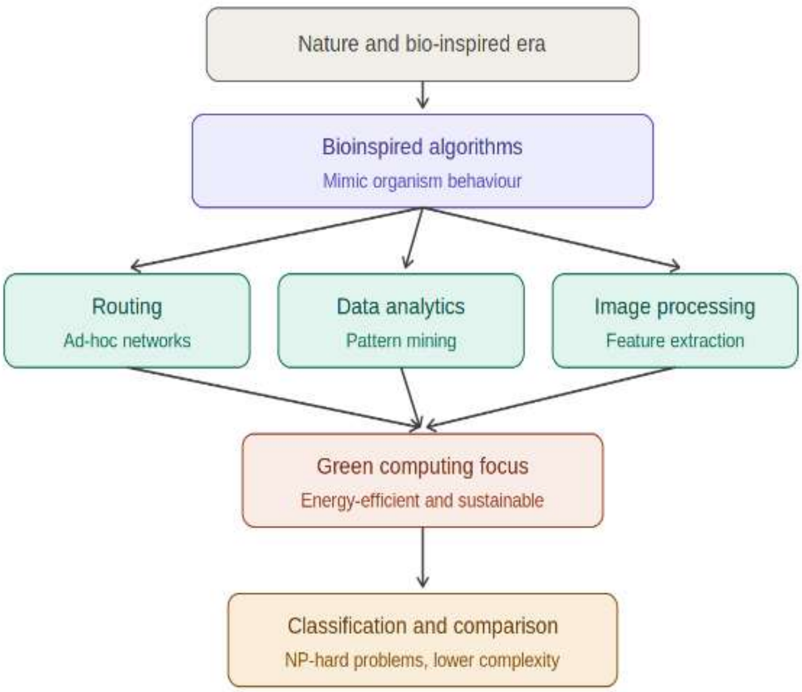
Received: 29 August 2026; Accepted: 03 September 2026; Published: 15 September 2026

ABSTRACT

In the current era, artificial intelligence plays a central role in driving technological advancements, a new age computing mechanism based on nature or bio inspired methodology came into existence. Bioinspired algorithms are algorithms which mimic the behaviour of organisms and are often linked with AI systems to guide goal-oriented organization. However, this methodology was implemented in early 90s, there is less research work done in this field. The past research shows the potential of such algorithms in various field like routing in ad-hoc networks, data analytics, and image processing. There is a growing need to apply nature-inspired algorithms in energy-sensitive environments, where solving complex problems must be balanced with computational efficiency and sustainability. The previous research results show that these algorithms have better capability than the traditional algorithms. The paper classifies all such algorithms which are efficient and open to use for more complex and NP hard problems. The focus is on their relevance to green computing and advantages such as design and lower computational complexity. The comparison of such algorithms is also done on different parameters so as to find out the optimality of these algorithms.

Keywords: data, analysis, inspired, computing

Graphical Abstract



ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VIII, August 2026

INTRODUCTION

Nature inspired algorithms (NIA) are the algorithms which are inspired from natural phenomenon. This means these algorithms observe the behavior of living organisms in nature i.e how they travel, how they navigate to their food source and how they interact with each other. This behaviour is incorporated into algorithms to solve complex problems.

These algorithms are intelligent in nature and provide solution for NP hard type problems. Earlier literature indicates that Nature-inspired algorithms often outperform traditional algorithms in domains like routing, clustering, and feature selection, particularly in handling NP-hard and high-dimensional problems. However, direct comparisons vary across datasets and metrics.

They are intelligent in nature and provide smart solution for NP hard problems. Their ability to mimic the animal behaviour in dynamic environment is one of the benefits of these algorithms. Therefore, these algorithms have potential to be used in dynamic scenario and highly complex problems. Thus, when compared with conventional routing algorithms, nature-inspired computing can create more reliable, intelligent, and effective systems.

Also, they do not need a lot of data to solve issues or adapt to new contexts which means that they can offer more privacy and security as well as a greater range of applications.

The paper consists of five sections. Section 1 discusses the introduction of bioinspired computing, their techniques and applications. A detailed recent literature review of bioinspired algorithms used in major data analytics and applications has been described in section 2. Section 3 discusses the methodologies behind nature inspired computing and a comparison on the basis of the concepts and parameters is stated. Open research issues are discussed in section 4 and lastly conclusion is stated in section 5.

Methodology & Scope of Survey

The objective of the paper is to classify and analyze Nature-inspired algorithms (NIAs) that have been applied to complex problems, particularly in the area of data analytics. The algorithms are selected on the basis of following: most commonly used NIA showing effectiveness in solving complex problems, frequent citation in last recent years, inclusion in benchmark datasets or empirical studies.

The analysis in the paper is based on reported empirical results across various application areas. The evaluation parameters used in the paper are accuracy, exploration-exploitation balance, computational complexity, and real-world applicability. The scope of the paper is limited to algorithms that have been used in data analytics problems. The algorithms not having empirical support or those used in unrelated domains were not included in the review.

LITERATURE REVIEW

The following literature cites the recent research work has been done using Nature-inspired algorithms in the areas of data and image processing:

This research proposes an effective framework for data preprocessing classification, using ant colony optimization (ACO) and particle swarm optimization (PSO) [1]. The volume and data variety have been used to mark the weight. The velocity and variety elements of big data have then been used to rank. The results of the trial show that the suggested procedures work significantly better than other methods already in use.

Ontology matching difficulties may have a solution in the form of Swarm Intelligent Algorithms (SIAs), namely the Beetle Swarm Optimisation Algorithm (BSO) [2]. The study focuses on a BSO-based approach to ontology alignment optimization. It is a technique that successfully manages memory usage while balancing the exploitation and exploration of algorithm. The study evaluated the efficacy of the algorithm using three pairs of real sensor ontologies. Sensor ontologies and other generic ontologies can be successfully aligned using SA-BSO-based ontology matching, according to statistics, especially in conference planning scenarios.

Because of the rapid advancement in data science, the high-dimensional datasets in machine learning are emerging. In order to choose the most discriminating features, this work suggests a unique hybrid binary dragonfly algorithm (HBDFA) that embeds a distance-based similarity evaluation method before the dragonfly algorithm (DA) searches [3].

The experimental findings demonstrate that HBDFA is better at searching high-dimensional data, improving classification outcomes, and selecting fewer features. One of the primary drawbacks of current meta-heuristic-based methods is that they frequently overlook the correlation between a set of chosen features [4]. For feature selection, the authors suggest a three-step genetic algorithm based on community detection. Additionally, the authors have contrasted the results of four other feature selection algorithms with the effectiveness of the suggested method. [5].

After discussing genetic algorithms (GAs) in the context of information theory, the paper develops a mathematical framework that includes, but is not limited to, big data. A whole new method for computational analytics is thus created by the efficiency computed here, which offers an incremental probabilistic technique to arrive at a solution that is exceptionally stable, evolutionary, and self-adjusting [6]. This study employs a time series based on Long Short-Term Memory Network (LSTM) optimization and Genetic method (GA) to accurately anticipate stock prices while accounting for the big data era trend. This study's findings also serve as a helpful guide for financial market analysis that makes use of large data and computer technology [7].

Microarray data is very important for gene-level cancer identification. Only a few distinctive genomes in the microarray sample exhibit notable cancer classification and identification rates. A well-known NP-hard problem is how to identify a limited number of distinctive genes from a big amount of microarray data. The F-score method and population variation enhanced artificial fish swarm algorithm are combined for implementing feature selection of gene expression from the microarray. Initially [8], many redundant and pointless features in the dataset's are removed via the F-score technique. The adaptive step and visual are used to modify the search space and to move the algorithm's range in various environments to improve the local optimization and global optimization abilities. Another study focusses on applying, modifying, and combining the firefly algorithm with other optimization methods to complex problems. The manuscript proposes and adapts a new version of the firefly algorithm (FA) [9] for the feature selection problem. The performance of the basic FA is greatly enhanced by the suggested technique, other metaheuristics in the context of COVID-19 data, based on benchmark accuracy scores.

In order to address some of the issues with meta-heuristic algorithms, a modified gray wolf optimizer algorithm was suggested [10]. Results from experiments show how well the suggested approach works to solve data clustering issues. Overall, the suggested technique has a lower intra-cluster distance than the others and yields the lowest average error rate of 11.22%. Another algorithm called Modified Cuckoo Search (MoCS) [11] was proposed. In order to prevent premature convergence, an effort has been made in this suggested work to balance the exploration of the Cuckoo Search algorithm with an increase in exploration potential.

Research Gap and Contribution

While numerous studies have proposed and examined nature-inspired algorithms for specific applications, there is a lack of consolidated insight that classifies these algorithms on the basis of their functional utility. For example: optimization, clustering, predictive modeling. The following contributions have been presented in the paper:

- A structured classification of major Nature-Inspired Algorithms (NIAs) based on their biological mechanism and computational design (e.g., swarm-based, evolutionary).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VIII, August 2026

- A comparative synthesis of their performance across diverse data analytics problems.
- Identification of application patterns highlighting where certain algorithms like PSO, GA, Firefly consistently outperform others in high-dimensional feature selection or clustering tasks.
- A detailed summary of algorithm-specific limitations, open challenges, and recommendations for future use.

Unlike prior surveys that focus narrowly on a single algorithm or domain, this work takes a cross-algorithm, cross-domain perspective intended to assist researchers in selecting appropriate NIAs for specific analytics tasks.

Commonly used Nature-inspired Algorithms in Data Analytics

In data analytics, several bio-inspired algorithms are widely used because if their capability to solve optimization problems, classification, and regression problems. The most commonly used bio-inspired algorithms in data analytics include: Genetic Algorithms (GA) is commonly used in data analytics for optimization tasks, including hyperparameter tuning, feature selection, and model optimization. Particle Swarm Optimization (PSO) is often used for global optimization tasks, including feature selection, hyperparameter tuning, and solving complex multi-objective problems. PSO is based on the movement of animal swarms which travel for food search. Ant Colony Optimization (ACO), the most frequent applications of ACO are in combinatorial optimization tasks including pathfinding, routing, and clustering. ACO simulates how ants leave pheromone trails in search of the shortest routes, based on their behavior. Genetic Programming (GP) is used in data analytics for evolving programs or mathematical expressions, often in symbolic regression, predictive modeling, and feature generation tasks. Artificial Bee Colony (ABC) Algorithm is used for problem optimization, especially in clustering and feature selection tasks, similar to PSO and GA. Inspired by the way bees forage, the algorithm uses a colony of fake bees to identify food sources (solutions) and communicate the quality of their results to help direct the search. Cuckoo Search (CS), machine learning and data analytics are two fields that leverage Cuckoo Search, a bio-inspired optimization method, to solve continuous and discrete optimization issues.

The following table classifies the categories of the algorithms which are used for data analytics:

Table 1: Summary of common nature-inspired algorithms used in data analytics, along with their roles, major advantages, limitations, and key application areas.

Algorithm	**Analytical Role**	**Advantages**	**Limitations**	**Key Applications**
Ant Colony Optimization (ACO)	Classification, Clustering	Good for discrete optimization, adaptable to dynamic environments	Sensitive to parameter tuning; may converge to suboptimal paths	Routing, logistics, data clustering
Particle Swarm Optimization (PSO)	Feature Selection, Optimization	Fast convergence, suitable for continuous optimization	Poor local search; risk of premature convergence	Hyperparameter tuning, neural network training
Artificial Fish Swarm Algorithm (AFSA)	Feature Selection, Pattern Recognition	High accuracy, flexible in search space	Balancing global vs. local search is difficult	Image processing, gene selection
Firefly Algorithm (FA)	Feature Selection, Classification	Balances exploration and exploitation; simple implementation	Weak global exploration in high-dimensional data	Bioinformatics, feature engineering

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VIII, August 2026

Artificial Bee Colony (ABC)	Optimization, Clustering	Strong exploitation, can handle complex objective functions	Needs many function evaluations; lacks memory of past solutions	Vehicle routing, WSNs, image segmentation
Genetic Algorithm (GA)	Feature Selection, Predictive Modeling	Robust search; handles noisy/incomplete data	Slow convergence; risk of redundancy	Model optimization, symbolic regression
Cuckoo Search (CS)	Clustering, Optimization	Efficient search via Lévy flights; easy to implement	Parameter sensitive; slow convergence in some cases	Pattern recognition, software testing

These Nature-inspired algorithms are powerful tools in data analytics because they offer flexible and effective strategies for solving a wide range of optimization and modeling challenges, often outperforming traditional methods when dealing with complex, high-dimensional, and noisy data. The table 2 summarizes the algorithms used till now in literature with the parameters and concepts used by them. The performance values presented in Table II are compiled from prior empirical studies. This paper does not include original experimental results; instead, it creates outcomes from existing literature in order to provide a comparative understanding of nature-inspired algorithms in data analytics.

Table 2: Performance of different NIA's

Algorithm	**Application Area**	**Dataset/Context**	**Evaluation Metric**	**Reported Result**
ACO (Ant Colony)	Data classification & preprocessing	Big data	Accuracy	ACO-SAW: 95% classification accuracy; limited in convergence speed
PSO (Particle Swarm)	Data classification & feature selection	Same as above	Accuracy	PSO-SAW: 98% accuracy; faster convergence than ACO
SA-BSO (Beetle Swarm)	Ontology Matching	Sensor ontology alignment	Match Score/Precision	Successful sensor ontology alignment; improved exploration-exploitation balance
FSA-PV (Fish Swarm)	Gene features selection	8 microarray datasets incl. Breast cancer	Accuracy	Over 90% accuracy in 8 cases; strong local/global search adaptation
HBDFA (Dragonfly Hybrid)	High-dimensional classification	COVID-19, spam, sports datasets	Accuracy	96.75% on COVID-19; >95% on Spam dataset
Firefly Algorithm	Feature selection	COVID-19 classification	Accuracy, Stability	Outperforms other metaheuristics in terms of COVID-19 data

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VIII, August 2026

Grey Wolf Optimizer	Clustering	Multiple real datasets	Error Rate	11.22% average error rate; lowest intra-cluster distance among seven methods
Genetic Algorithm (GA)	Time-series prediction	Stock price prediction with LSTM	MAE, RMSE, R^2	R^2 = 0.87; MAE = 2.41; demonstrates stable, evolutionary model tuning
Modified Cuckoo Search	Data clustering	15 benchmarks + 6 real datasets	Convergence, Accuracy	Outperformed PSO, ACO, ABC, and standard CS in cluster center optimization

The study shows the evaluation results (e.g., accuracy, convergence performance, error rates) from previously published research. Metrics such as convergence time, F1-score, and computational complexity vary across studies and were reported as available in the literature.

Open Issues & Ecological Impact

Since Nature-Inspired algorithms address high-dimensional, complex optimization problems, they are important in the field of data analytics. These algorithms are especially helpful when the conventional approaches are computationally costly or ineffective. Below is a breakdown of how NIAs can used for different segments-

Optimization of Models and Parameters

Algorithms like GA, PSO, and ACO are frequently used to tune hyperparameters in machine learning models [12]. They are particularly effective for global optimization, avoiding the local optima traps typical in gradient-based methods. Many nature inspired algorithms, like GA and PSO can identify the most important features in large datasets resulting into improved model accuracy, reducing overfitting, and speeding up computation.

Clustering and Classification

Swarm-based algorithms like PSO and ACO, can be used to discover clusters in data, optimizing cluster centroids or partitions, especially when there are huge clusters. They adapt to different types of data distributions and provide robust solutions. NIA can be used to improve the performance of classifiers, by optimizing the decision boundary and parameters. For example, GA is used to evolve better feature sets or classifiers, improving the predictive accuracy.

Data Mining and Pattern Recognition

Evolutionary algorithms can be used to detect complex patterns in data, such as in time-series forecasting, anomaly detection, or image recognition. [13] These algorithms work by evolving a population of candidate solutions to learn patterns or classify data. NIAs can help discover hidden patterns, relationships, or trends in large datasets. For example, Genetic Programming (GP) can be used to evolve decision trees that shows underlying patterns in the data.

Multi-Objective Optimization

Many real-world problems involve optimizing more than one objective simultaneously. For instance, in data analytics, we might need to balance accuracy with computational efficiency. Nature-inspired algorithms, such as Multi-Objective Evolutionary Algorithms (MOEAs), are particularly effective in solving these types of problems by providing a set of optimal trade-offs [14].

Robustness to Noisy and Complex Data

NIAs are capable of dealing with noisy, incomplete, and highly complex data [15]. This is due to their exploration and exploitation mechanisms. They can search for global optima in complex problem spaces, rather than getting stuck in local optima, as traditional algorithms often do.

Energy Efficient Computing- For Eco-Friendly Environment

Nature-Inspired Algorithms align well with the sustainable computing practice due to their lightweight, decentralized, and adaptive characteristics, which contribute to energy efficiency and resource optimization. Usman, M.J., et al., reviewed Nature-Inspired algorithms used in cloud datacenters to solve energy issues.[16]

Jamil, M., at al., [17] suggested that these algorithms can be considered for energy consumption after a thorough analytical study.

Key contributions of NIAs include:

- **Reduced Computational Complexity**: Many NIAs, such as PSO and ACO, operate using population-based search rather than heavy iterative training, reducing CPU/GPU load compared to deep learning methods.
- **Lower Memory Footprint**: These algorithms require minimal storage for intermediate states, making them ideal for deployment in low-resource environments such as IoT and edge computing.
- **Energy-efficient Execution**: Due to their heuristic and metaheuristic nature, NIAs can converge to acceptable solutions quickly, thus saving processing time and power.
- **Sustainability in Data Centers**: When integrated into scheduling or resource allocation, NIAs have been shown to optimize task distribution, reducing idle time and power wastage in distributed systems.

For example, Firefly and Grey Wolf Optimizers have been successfully used in load balancing and server allocation tasks in cloud environments to minimize energy consumption.

CONCLUSION

Nature inspired algorithms have strong data analytics capabilities, especially when working with massive, noisy, complicated, high-dimensional datasets. The paper briefly discusses how NIAs are important in domains like machine learning, artificial intelligence, and financial market analysis. They have the ability to effectively explore complex solution spaces and adjust to changing inputs. As data analytics continues to grow in complexity, the use of these algorithms is likely to rise.

NIAs can help in providing efficient, scalable, and accurate methods for decision-making and problem-solving across various industries. This review presents comparative performance results from existing studies. In this study, the absence of standardized evaluation protocols and unified datasets limits direct algorithm-to-algorithm comparisons. Future work should include benchmarking nature-inspired algorithms using consistent datasets and metrics such as F1-score, convergence time, precision, recall.

REFERENCES

1. Dubey, A. K., Kumar, A., & Agrawal, R. (2020). An efficient ACO-PSO-based framework for data classification and preprocessing in big data. Evolutionary Intelligence, 14(2), 909–922. https://doi.org/10.1007/s12065-020-00477-7
2. Haroon, P. S., Patil, S. N., Divakarachari, P. B., Falkowski-Gilski, P., & Rafeeq, M. D. (2024). An optimized system for sensor ontology meta-matching using swarm intelligent algorithm. Internet Technology Letters, 7(1), e498. https://doi.org/10.1002/itl2.498

3. Bangyal, W., Nisar, K., Soomro, T., Ibrahim, A. A., Mallah, G., Hassan, N., & Ur Rehman, N. (2022). An improved particle swarm optimization algorithm for data classification. Applied Sciences, 13(1), 283. https://doi.org/10.3390/app13010283
4. Dinç, B., & Kaya, Y. H. (2024). HBDFA: An intelligent nature-inspired computing with high-dimensional data analytics. Multimedia Tools and Applications, 83(1), 11573–11592. https://doi.org/10.1007/s11042-023-16039-9
5. Rostami, M., Berahmand, K., & Forouzandeh, S. (2021). A novel community detection-based genetic algorithm for feature selection. Journal of Big Data, 8, 2. https://doi.org/10.1186/s40537-020-00398-3
6. Hasan, M. (2014). Genetic algorithm and its application to big data analysis. International Journal of Scientific & Engineering Research, 5(1), 1991–1996. http://www.ijser.org/researchpaper/Genetic-Algorithm-and-its-Application-to-Big-Data-Analysis.pdf
7. Sha, X. (2024). Time series stock price forecasting based on genetic algorithm (GA)-Long Short-Term Memory Network (LSTM) optimization. arXiv preprint, arXiv:2405.03151. https://arxiv.org/abs/2405.03151
8. Li, Z.-Z., Wang, F.-L., Qin, F., Yusoff, Y. B., & Zain, A. M. (2024). Feature selection of gene expression data using a modified artificial fish swarm algorithm with population variation. IEEE Access, 12, 72688–72706. https://doi.org/10.1109/ACCESS.2024.3402652
9. Bacanin, N., Venkatachalam, K., Bezdan, T., Zivkovic, M., & Abouhawwash, M. (2023). A novel firefly algorithm approach for efficient feature selection with COVID-19 dataset. Microprocessors and Microsystems, 98, 104778. https://doi.org/10.1016/j.micpro.2023.104778
10. Ahmadi, R., Ekbatanifard, G., & Bayat, P. (2020). A modified grey wolf optimizer based data clustering algorithm. Applied Artificial Intelligence, 35(1), 63–79. https://doi.org/10.1080/08839514.2020.1842109
11. Mohanty, P. P., & Nayak, S. K. (2021). A modified cuckoo search algorithm for data clustering. International Journal of Applied Metaheuristic Computing, 13(1), 1–32. https://doi.org/10.4018/IJAMC.2022010101
12. Gad, A. G. (2022). Particle swarm optimization algorithm and its applications: A systematic review. Archives of Computational Methods in Engineering, 29, 2531–2561. https://doi.org/10.1007/s11831-021-09694-4
13. Gomez-Rosero, S., & Capretz, M. A. M. (2024). Anomaly detection in time-series data using evolutionary neural architecture search with non-differentiable functions. Applied Soft Computing, 155, 111442. https://doi.org/10.1016/j.asoc.2024.111442
14. Cinalli, D., Martí, L., Sanchez-Pi, N., & Garcia, A. C. B. (2016). Bio-inspired algorithms and preferences for multi-objective problems. In F. Martínez-Álvarez, A. Troncoso, H. Quintián, & E. Corchado (Eds.), Hybrid Artificial Intelligent Systems (pp. 231–243). Springer. https://doi.org/10.1007/978-3-319-32034-2_20
15. Jakšić, Z., Devi, S., Jakšić, O. M., & Guha, K. (2023). A comprehensive review of bio-inspired optimization algorithms including applications in microelectronics and nanophotonics. Biomimetics, 8(1), 7. https://doi.org/10.3390/biomimetics8010007
16. Usman, M.J., Ismail, A.S., Abdul-Salaam, G. et al. Energy-efficient Nature-Inspired techniques in Cloud computing datacenters. Telecommun Syst **71**, 275–302 (2019). https://doi.org/10.1007/s11235-019-00549-9
17. Jamil, M., Kor, AL. Analyzing energy consumption of nature-inspired optimization algorithms. GRN TECH RES SUSTAIN **2**, 1 (2022). https://doi.org/10.1007/s44173-021-00001-9