

# Bio-Inspired Optimization: Algorithm, Analysis and Scope of Application

Dr N. Kalaivani, Mr. Naveen N

Assistant Professor, Department of Information Technology, Sri Krishna Adithya College of Arts and Science, Coimbatore, Tamil Nadu, India. [kalaivanin@skacas.ac.in](mailto:kalaivanin@skacas.ac.in)

Student, Department of Information Technology, Sri Krishna Adithya College of Arts and Science, Coimbatore 641042, Tamil Nadu, India. [naveen.n12406@gmail.com](mailto:naveen.n12406@gmail.com)

## Abstract

Bio-inspired optimization methods have really taken off in recent years, showing up everywhere from computer science to biology and math. Lately, there's a clear shift toward these algorithms because they handle tough optimization problems that trip up more traditional approaches. They work with both linear and non-linear functions and tackle the kinds of challenges where old-school methods fall short. Right now, the big names in this field are Particle Swarm Optimization (PSO), Genetic Bee Colony (GBC), Fish Swarm Algorithm (FSA), Cat Swarm Optimization (CSO), and the Whale Optimization Algorithm (WOA). These five algorithms are leading the way in bio-inspired optimization.

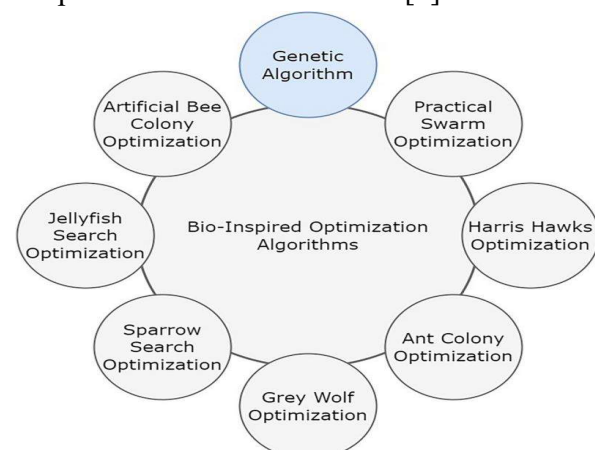
**Keywords:** *Particle swarm optimization (PSO), Genetic Bee Colony (GBC), Fish Swarm Algorithm (FSA), Cat Swarm Optimization (CSO), Whale Optimization Algorithm (WOA).*

## 1. INTRODUCTION

The process of identifying the most optimal solution among a set of several solutions for a problem is termed as optimization. Life presents numerous situations wherein an optimal solution needs to be identified for effective application, for example, for overcoming costs, energy savings, or improving performance. Currently, biological algorithms solve application problems in different areas of science, including decision-making, management of information, or optimization.

Bio-inspired optimization methods will soon be more successful in addressing failure or anomaly detection problems using various current methodologies [1]. Single or multi-objective problems that use deterministic or stochastic approaches rely more on

optimization [2]. Bio-inspired methods are smarter, improved, verifiable, and more adaptable than traditional ones [3].



In the modern era, application of bio-inspired algorithm techniques is found in computer networks, security, mechanics issues, electronics image processing, electrical, robotics, production engineering, management, planetary, and many

other areas to solve problems easily and effectively [4, 5].

The topic introduced in this research work is bio-inspired algorithms, which are designed using only identifiable and distinct biological entities. Particle Swarm Optimization (PSO), Genetic Bee Colony (GBC), Fish Swarm Algorithm (FSA), Cat Swarm Optimization (CSO), and Whale Optimization Algorithm (WOA) are five bio-inspired algorithms.

## II. OVERVIEW OF OPTIMIZATION

### II.I. Optimization with Stochasticity

However, due to randomness in the function of either minimization or maximization in order to propose solutions in real-world problems, the stochastic optimization computing procedure is more ambiguous or imprecise. The uncertainty in the procedure involved is expressed as noise. Stochastic optimization spends a lot of its endeavors on applications specific to short as well as long programs. Examples of applications of SO include drug development, airplanes, missiles, as well as managing traffic on a network. Even though stochastic optimization is a very effective modeling tool with few applications, approximation of real-world problems is another major field in which applications of SO in problems are of practical limitations.

### II.II. Sturdy Optimization

It is termed the process of changing results that continue to remain valid indeed if there's query in the input variables. This helps in making sure that the result of an equation or expression will be safe from attacks by taking its worst-case results. It can be termed as an extremely useful system since delicacy or robustness of results safety closely relates to cost-saving structural designs. It has its operating areas in trustability Optimization or Engineering Design.

### II.III. Adaptive Optimization

The term dynamic programming is the other name that can be utilized to describe dynamic optimization, in which the optimal pattern for a number of parameters within a system that may be applied in changing a result to a particular problem is examined. There are colorful forms that can be utilized in dynamic optimization.

The Schedule Issues and Dynamic Programming are two exemplifications

## III. Optimization Algorithms Inspired by Biology

Bio-inspired optimization algorithms are those that seek to solve difficult issues by emulating the behavior of live things. They are intelligent, adaptive, and can handle complex or nonlinear tasks which are difficult to deal with by other approaches.

### III.I. Particle Swarm Optimization (PSO)

A nature-inspired algorithm, Particle Swarm Optimization takes its inspiration from fish as well as bird social behavior. Originally, Craig Reynolds simulated flock social birds that were later examined by Frank Heppner in his suggested PSO mechanism. The algorithm is inspired by intelligent birds. In each step, the position and velocity of these particles are updated. Every particle retains its best solution to date known as pbest. It is also informed about the best answer of the group known as gbest. PSO is widely adopted for a host of industries including energy systems, engineering, scheduling, planning, and even visual effects in motion pictures.

#### Benefits of PSO

- **Faster Convergence:** It accelerates the convergence toward the best solution.
- **Simplicity:** Updates are easy to calculate in location and velocity equations.

- **Environmental adaptability:** can choose the best options in any environment that is in flux.

Some disadvantages of PSO are inability to discover many optima and keeping the assumption that all particles being identical, so inertial and velocity will remain the same. The deficiency of storage and inability of differentiating between the positions of prior and subsequent particles are issues which PSO cannot address.

### III.II. Colony of Genetic Bees (GBC)

A bio-inspired optimization algorithm known as Genetic Bee Colony (GBC) is modeled based on the foraging behavior of honeybees. The algorithm differentiates bees into three types: scout bees, spectator bees, and employed bees. The variables communication link, task assignment, reproduction, dancing, assignment, mating, and motion influence the selection of the most appropriate bee depending on the scenario. GBC is very simple, flexible, and efficient in finding the global optimum despite being slow and prone to being trapped in a local optimum. GBC has been applied in training neural networks, scheduling tasks, clustering, and function optimization. Other real-world applications of GBC include decision-making, scheduling, assignment problems, searching, incantation, determination of limits, and problems in a network.

#### Advantages of GBC

The ABC technique is a population-based technique that has very few control parameters and a simple and flexible structure that achieves a global optimal solution by employing a mathematical model of honeybee behaviors. Various applications, including optimizing functions, real-parameter optimization problems, digital filter designs, clustering, and training neural

networks, have utilized ABC optimization techniques.

#### Disadvantages of GBC

Include its slower speed of convergence and less accuracy in computing big problems. In long-term problems, GBC may face problems of early convergence. The population could either be non-autonomous or of fixed size.

### III.III. Fish Swarm Algorithm (FSA)

The motivation behind creating the Fish Swarm Algorithm (FSA) is derived from the nature of fish movements in a water body. Each fish possesses a characteristic of moving towards areas where there is a higher concentration of food. It is well known that FSA is able to move out of a local minimum. Modifications have been applied to ensure it is fast and accurate. Each fish possesses a characteristic of moving larger distances in search of a larger habitat. Every fish has a freedom to move away from a negative situation at any stage. It is possible to achieve poor sustainability if there is some deficiency in larger values. With a larger visual perspective of FSA, there is a possibility of use of both local search and global search.

#### Advantages of FSA:

Like GBC, FSA provides better convergence ability and versatility. It also shows preciseness and error tolerability. The Not applicable for globally convergent problems. It transfers information if there is a low search rate. It will prove highly resilient, have the capability of searching globally, tolerate parameters, and remain insensitive to initial values.

#### Disadvantages of FSA:

Wireless sensor networks, tracking, medical estimation, segmentation, clustering, regression, image processing, calibration, localization, and

power systems are the areas in which FSA is incorporated into the solution.

FSA has also been applied for problems related to networks, resource management, and image processing.

#### **III.IV. Cat Swarm Optimization (CSO)**

Cat swarm optimization (CSO) - Cat swarm optimization is another bio-inspired intelligence technique developed by Chu et al. In this technique, all nodes are assumed to move virtually within defined regions like cats for finding the optimum solution. The number of cats is fixed for both modes and defined by a predefined few cases ratio known by MR. The N virtual cats are placed randomly. Unprocessed and processed cats are differentiated for each dimension according to the MR value set by 0 and 1. Tracing stops if there are no cats left. The coordinate trace nodes will then give the optimum solution at the end. In the seeking mode, the cats' action is conservative and slows down. Voltage stability, Economically Dispatch on the Transmission Systems, Hybrid Generation Schemes, Job Scheduling, Data Mining, Scheduling of Projects, Optimal Contract Capacity, Global Numeric Optimization Problems.

#### **Benefits of CSO :**

CSO is Simple to build and easy on parameters to tune. The approach is robust, May converge quickly, obtain global solution, overlap, and mutate. Have computational speed timeless. Find exact models in math and Uncover optimal fast solutions. Adjust to modification in new system and driven by random choice. Demerits of CSO : Being descriptive for initial parameters takes time. COA will not result in better convergence for the scattering type of problem and even for complex it might converge faster if it is stuck in those problems. The time to converge and towards convergence will take more for multi-

objective and larger-sized problems.

#### **III.V. Whale Optimization Algorithm (WOA)**

Whale optimization algorithm developed by Mirjalili et al. Whale Optimization Algorithm (WOA) is based on the hunting behavior of humpback whales, specifically the "bubble-net feeding" method. In this algorithm, each whale in the population is a candidate solution in the search space. Using this algorithm, whales can surround their targets, namely the current-best solution, and then adjust their position. There are two modes of operations for whale optimization algorithm. The two modes of operations have been named as exploitation and exploration.

A new optimization algorithm for the task of tackling optimization problems. It should be highlighted here that the "bubble-net feeding" is a distinct phenomenon, and this could occur in humpback whales alone.

In this research, the spiral "bubble-net feeding" is formally modeled in order to conduct optimization tasks.

#### **Advantages of WOA:**

Whale optimisation algorithm overcomes local optima problem and has the capability of computing local and global optima values for any optimization task, whether constrained or unconstrained. In the process, it even does not require any structural change of arrangement or change of value. Exploration of best solution takes place with computation of solution done simply, easily, performed at a faster rate. Quality of solution improved, converges to a result faster.

#### **Demerits of WOA :**

WOA is not suitable in a large spaced problem takes much more time to explore and converge. The quality of the solution is questionable. The optimal solution cannot be

identified to optimize problems to solve a high dimensional problem. The randomness method of the basic WOA algorithm is complicated. Harmony between exploration and exploitation stages is absent.

#### IV. COMPARISON OF BIO INSPIRED ALGORITHM

- **PSO:** Converge quickly with pbest and gbest, although may trap in local optima.
- **GBU:** It merges the search procedure performed by the bee colonies with the genetic operators. It is suitable for discrete and complex problems
- **FSA:** It employs the concept of the fish swarm for the search process; very effective but slow.
- **CSO:** Models cats' search and tracing; good exploration vs. exploitation trade-off.
- **WOA:** Based on whaling; excellent global search capabilities and avoids local optima easily and simply.

#### V. ISSUES, CHALLENGES, AND FUTURE DIRECTIONS

Bio-inspired optimization algorithms have made real progress when it comes to tackling tough optimization problems. Still, they face a few stubborn challenges. The biggest headache is finding the right balance between exploring new solutions and sticking with the best ones found so far. A lot of algorithms lock in too early and get stuck in local optima, especially when the search space gets really big. Then there's parameter tuning — getting the control settings just right can make or break the performance and speed of an algorithm. Scalability isn't easy either. When you try to use these algorithms on larger or real-time problems, they can chew up way more computing power and time than expected. Some struggle with slow convergence or end up giving inconsistent

results because of all the randomness built in. Plus, since there aren't always strong theoretical guarantees for convergence or finding the best solution, people can be wary about using them for critical tasks. Looking ahead, research needs to focus on building hybrid and adaptive algorithms that pull together the best parts from different approaches. This could boost both accuracy and stability. Bringing in machine learning for on-the-fly parameter adjustment, or to help these methods adapt in changing environments, looks promising too. There's also a lot of value in speeding up convergence, making algorithms more robust, and making sure they work on big, real-world problems. All of this will help bio-inspired optimization really make its mark where it counts.

#### VI. CONCLUSION

Bio-inspired optimization algorithms offer powerful, flexible tools for solving problems that stump traditional methods. In this paper, I gave an overview and compared five of the most popular bio-inspired algorithms: PSO, GBC, FSA, CSO, and WOA. Each one comes with its own strengths and weaknesses, depending on the problem at hand. As these techniques keep evolving — especially with more hybrid approaches — they're set to become even more important in both research and real-world applications across all sorts of fields.

#### VII. ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Dr. N. Kalaivani, Assistant Professor, Department of Information Technology, Sri Krishna Adithya College of Arts and Science, Coimbatore, India, for her valuable guidance, continuous encouragement, and constructive suggestions throughout the course of this research work. The authors also acknowledge the dedicated efforts and contribution of Mr. Naveen N, whose consistent involvement and commitment were

instrumental in the successful preparation and completion of this study.

optimisation for wsns. *Sensors*. 2018;18(10):3351

### VIII. REFERENCES

- [1] Mishra KK, Tiwari S, Misra AK. Bio inspired algorithm for solving optimization problems. In: 2011 2nd International Conference on Computer and Communication Technology (ICCCT-2011). Allahabad, India: Motilal Nehru National Institute of Technology; 2011. pp. 653-659. DOI: 10.1109/ICCCT.2011.6075211
- [2] Hammod WA, Zamil K, Ali A. A review of bio-inspired algorithms. In: A Conference: (SOFTEC Asia 2017). Malaysia: Kuala Lumpur Convention Centre; 2017
- [3] Das S, Suganthan PN. Differential evolution: A survey of the state-of-the-art. *IEEE Transactions on Evolutionary Computation*. 2011;15(1):4-31
- [4] Fan X, Sayers W, Zhang S, et al. Review and classification of bio-inspired algorithms and their applications. *Journal of Bionic Engineering*. 2020;17: 611-631
- [5] Kar AK. Bio-inspired computing—A review of algorithms and scope of applications. *Expert Systems with Applications*. 2016;5:20-32
- [6] Swarm intelligence based energy efficient clustering algorithms for WSN: A review of algorithms, analysis and scope of applications. Chapter 5, Resource optimization using swarm intelligence and the IoT
- [7] Gourtani A, Nguyen TD, Xu H. A distributionally robust optimization approach for two-stage facility location problems. *EURO Journal of Computation Optimization*. 2020;8:141-172
- [8] Li X, Keegan B, Mtenzi F. Energy efficient hybrid routing protocol based on the artificial fish swarm algorithm and ant colony