Bio-inspired Computing: Bio-inspired Algorithms and Applications

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Contents

Introduction

- Nature has inspired computing to a great extent.
- Tests were created to determine if a machine could think like Human.
- The variety, adaptability and sophistication of the natural world has led to the development of efficient, flexible and robust algorithms.
- With increased data explosion and computational complexity, the need for efficient solutions has emerged.
- Intelligent meta-heuristics algorithms like Bio-inspired algorithms resolve complex issues with optimized solutions.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

[3]Josh Bongard, Biologically Inspired Computing

Recent History of Bio-inspired Computation

- During the last decades, Bio-inspired Computation has emerged as the most studied branch of Artificial Intelligence.
- Increased number of algorithms are introduced and gaining acceptance and prominence.
- Limited visibility of the newly created algorithms due to recent development might lead to force-fitting of popular algorithms for various use cases.
- Most of the recently developed bio-inspired algorithms support multi-objective problems.

[5]Javier Del Ser, Bio Inspired Computation:Where we stand and What's next.

Evolution of Bio-Inspired Algorithms

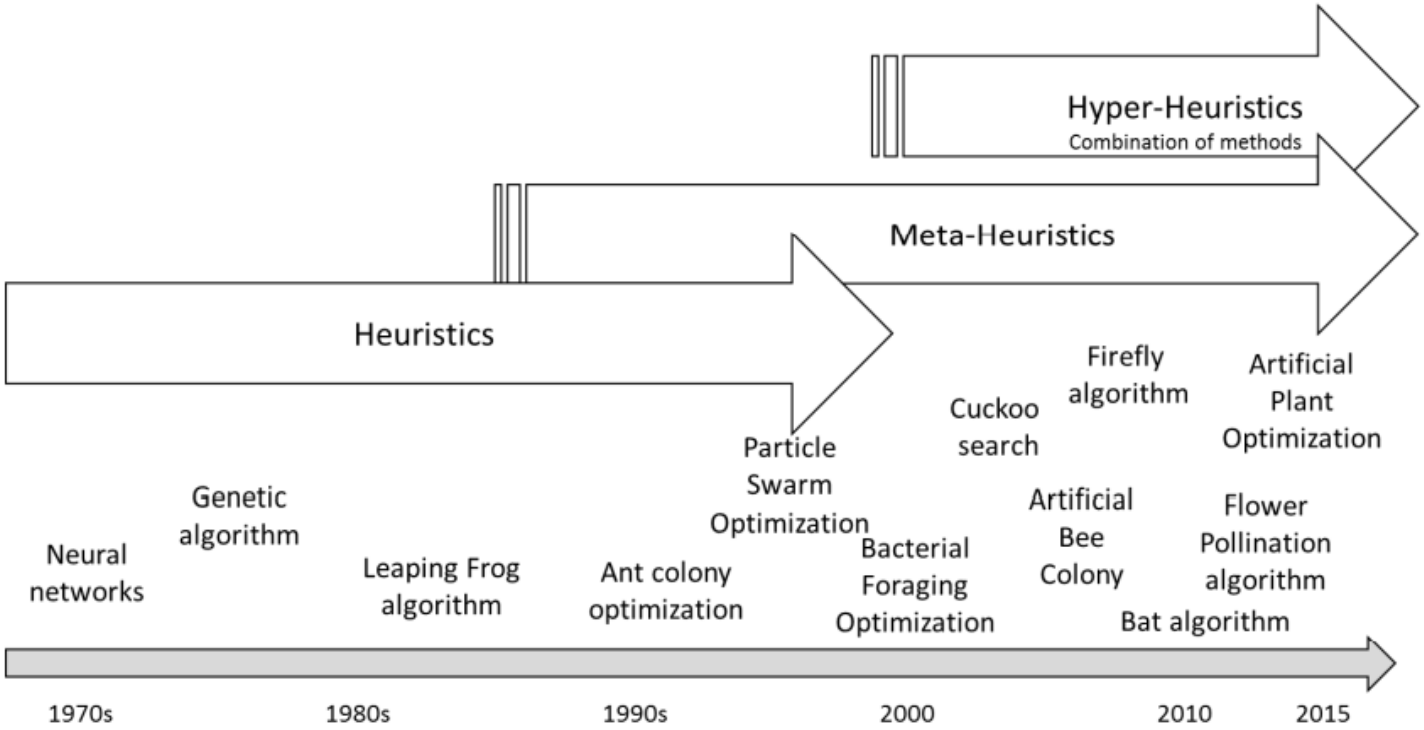

Figure: Development of Bio-inspired Algorithms with time

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

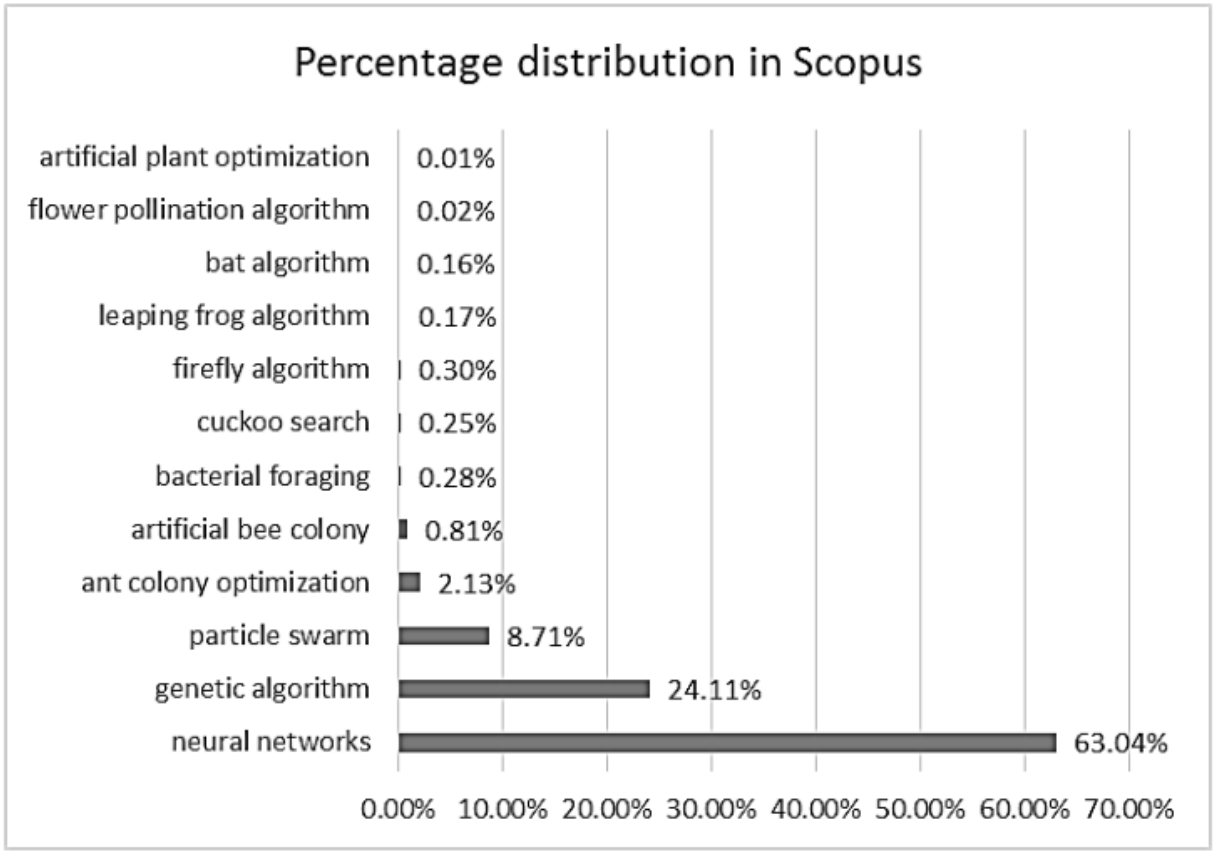

Figure: Percentage Distribution in Scopus of the twelve slightly popular algorithms

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Review of Algorithms and their Applications

Neural Networks

- Neural Networks replicate the neurons in any intelligent organism.
- These self-adapting and self-organizing algorithms combine several processing units connected in a network in multiple layers.
- Supervised, Unsupervised and Reinforcement based learning techniques are used to train Neural Networks.

Applications

- Neural networks find extensive usage in pattern recognition, problem detection, rule base association, classification problems, time-series prediction and non-linear regression.
- Language and Speech modelling tasks have been possible through deep learning in recurrent neural networks.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

[4]Willam Sayers, Hassan Chizari, Shu-jun Zhang, Review and Classification of Bio-Inspired Algorithms and Their Applications.

Genetic Algorithm

- It is an evolutionary algorithm that mimics natural selection.
- Specific fitness drivers need to be computed in order to obtain a suitable solution.
- Genetic Algorithm uses four basic operators namely reproduction, mutation, crossover and inheritance.
- Fails to address complex high-dimensional and multi-modal problems.

Applications

- In industrial domain for job scheduling,project selection and network analysis.
- In solving multi-variate decision making, parallel computation problems, navigation and load balancing.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

[2]Amrita Chakraborty, Arpan Kumar Kar, A Review of Bio Inspired Computing Methods and Potential Examples.

Leaping Frog Algorithm

- Inspired by the food hunting mechanism of frogs.
- Virtual frogs represented as vectors are partitioned into sub-populations called memeplexes and sub-memeplexes.
- The worst frog from each sub-memeplex takes a leap towards food source.
- If the new position is better, the process repeats. Else a new frog is created randomly.
- Until the whole population is shuffled and the termination condition is satisfied, the process repeats.

Applications

- It is used in network scaling, cost minimization problems, permutation-based searching and optimization problems.
- It is computationally complex to implement.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Ant Colony Optimization

- It is inspired by communication between ants while foraging. Ants direct each other by laying pheromones while exploring the environment.
- In the algorithm, pheromones serve as numerical information used to form solutions based on probabilistic search experience.
- Design variables are decided to create candidate solutions and the optimal candidate solution is chosen using parametric probability distribution.

Applications

- It is used for searching and optimization based problems.
- Prominent use cases in signal processing systems, satellite control, target tracking and social graph mining.

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[4]Willam Sayers, Hassan Chizari, Shu-jun Zhang, Review and Classification of Bio-Inspired Algorithms and Their Applications.

Particle Swarm Optimization

- Inspired by collective behaviour of a school of fishes, a swarm of insects or a flock of birds.
- Feedback of the group is taken into account for meeting the objective.
- Suited for problems where the function to be optimized is discontinuous and has non-linearly related parameters.
- Suitability of the candidate solution based on fitness function is evaluated by each member of the swarm.

Applications

- It is used in deterministic and constraint-based optimization problems.
- Used in scheduling, segmenting digital images and multi-criteria decision problems.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Bacterial Foraging Optimization

- Based on the elimination of organisms with poor abilities to locate or ingest food for survival.
- Assumption that organisms search and obtain food in a way that maximizes their energy intake per unit time spent on food search.
- Operators like swarming, reproduction, chemotaxis and elimination-dispersal to find optimal solution.

Applications

- It is used in multi-objective problems,dynamic resource allocation, pattern recognition and job scheduling.
- Poor convergence capability for complex optimization problems.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Cuckoo Search

- Inspired by the breeding behaviour of the cuckoos.
- Co-operative breeding, nest takeover and intra-specific brood parasitism is imitated by the algorithm.
- The nests in which eggs are to be laid and new candidate solution generation are identified through a Levy flight.
- Re-distribution and mixing of eggs in order to find a optimal solution.

Applications

- Used in multi-objective scheduling and allocation problems.
- Path identification for network analysis and knapsack problems.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Artificial Bee Colony

- Inspired by the communication, task allocation, foraging, site selection and mating behaviours of honey bees.
- This optimization algorithm finds the most optimal numerical solution.
- Fitness functions based on various parameters derive a number of candidate solution.
- Based on the suitability, the most optimal solution is selected.

Applications

- Used in routing and task allocation problems.
- It can be used to optimize multi-modal and multi-variate problems.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Firefly Algorithm

- Inspired by behaviour of fireflies involving luminescent signalling and avoiding being preyed.
- A population of fireflies is created and fitness parameters are modified to obtain the best suited solution.This happens iteratively, until a best solution is obtained.
- Firefly algorithms gives better performance over other swarm algorithms with multi-modal functions.

Applications

- Used with multi-modal functions, NP-hard problems, continuous and discrete search problems.
- Can be combined with other algorithms for optimization.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Bat Algorithm

- It uses the echolocation behaviour of bats to find food and prey.
- Unless a prey or food source is reached, the flight velocity and frequency and loudness of the cry is adjusted iteratively.

Applications

- Used for clustering, vector matching, multi-values system based and multi-objective optimization.
- Better performance than Genetic Algorithms and Particle Search Optimization in constrained optimization tasks.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Flower Pollination Algorithm

- It is inspired by the pollination mechanism in flowers.
- The pollination process would enable the best candidate solution vector to be stimulated.
- The process runs iteratively evaluating random candidate solution vectors.

Applications

- Finds application in civil engineering, energy management, emission control, electromagnetism and linear programming problems.
- Used in global optimization problems and high complexity convergence problems.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Artificial Plant Optimization

- Inspired by growth mechanism in plants.
- Oxygen, water and sunlight affect photosynthesis. Considering Oxygen and water would be distributed equally, the plant growth would be affected if light is not uniformly distributed.
- Phototropism is used to find an optimal solution, the case in which the plant growth takes place in the direction of light.

Applications

- Used in global optimization problems like protein folding, wireless senor networks
- Finds application in network configuration simulation and molecular structure analysis.

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Evolution in Algorithms with increased complexity

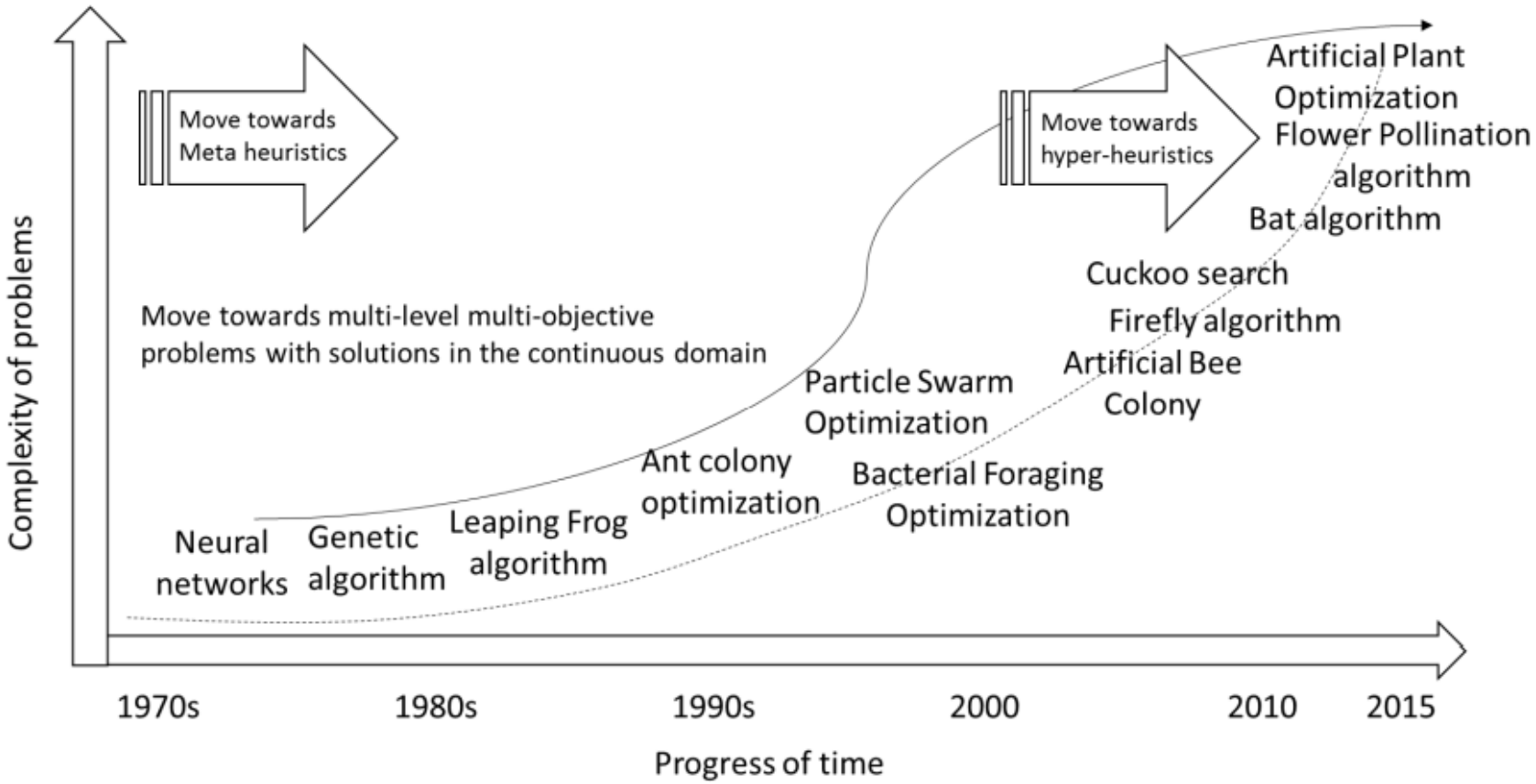

Figure: Evolution of Bio-inspired algorithms with increase in complexity of problems

[1]Arpan Kumar Kar, Bio Inspired Computing - A Review of Algorithms and Scope of Applications.

Future Scope

- Optimization of the newly-developed algorithms like flower-pollination, bat algorithm, leaping frog algorithm to make it more popular like neural networks and Ant Colony Optimization.
- Application of bio-inspired algorithms not only in engineering, but also in cross-domain fields, e.g. applying neural networks in production management and supply-chain management.
- Exploration and theoretical understanding of further newly developed algorithms like bird based algorithms namely eagles and doves and animal based algorithms like monkeys,lions, wolves and sharks.
- Developments and further understanding of these algorithms would enable to determine optimal algorithms as per the use case.

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References

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Thank you for your attention.