Study: Evolution of Nature Inspired Algorithms in Various Application Domains

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Abstract— Nature is the best guide and its outlines and qualities are to a great degree monstrous and abnormal that it offers motivation to looks into to impersonate nature to take care of hard and complex issues in computer sciences. Bio Inspired figuring has come up as a new period in calculation covering extensive variety of uses. The Nature inspired algorithm are in hype with more impactful results in various application domain. This paper consist of detailed study about the recent advances in nature inspired optimization methods. This paper also gives the flash light over the various optimization algorithm with its aim. Moreover, it includes the comparative study between the Swarm intelligence algorithms. It also discusses the applicability of various algorithm. These kind of nature-inspired algorithms are used widely in various fields for solving a variety of problems like travelling agent problem, in bio-information, in scheduling, clustering and mining problems, image processing, engineering designs.

Key words: Nature Inspired Algorithm, Swarm Intelligence, Optimization, Optimizing Algorithms, Comparison, Applicability

I. Introduction

Natural Computing, additionally called natural computation, is a wording acquainted with envelop three classifications of strategies:

– Those that call for motivation from nature for the improvement of novel issue working methods;
– Those that depend on the work of computers to combine characteristic marvels;
– Those that utilization regular materials (e.g., atoms) to work out. The essential regions of research that make these three branches are artificial neural networks, evolutionary algorithms, swarm knowledge, fake insusceptible frameworks, fractal geometry, manufactured life, DNA figuring, and quantum processing, among others.

A. *Nature - Inspired Models of Calculation*

The most "established" nature – inspired models of calculation are computation are cellular automata, neural computation, and evolutionary computation. Later computational frameworks, abstracted from natural processes include swarm intelligence, artificial immune systems, membrane computing, and amorphous computing.

II. Nature-inspired models of calculation

– Cellular automata
– Neural computation
– Evolutionary computation
– Swarm intelligence
– Artificial immune systems
– Membrane computing
– Amorphous computing

Swarm intelligence and bio-inspired algorithms form a hot subject in the developments of new algorithms inspired by nature. These nature-inspired meta heuristic algorithms can be based on swarm intelligence, biological systems, physical and chemical systems. Though not all of them are efficient, a few algorithms have proven to be very effective and hence have become popular tools for solving real-world problems. Some algorithms are insufficiently studied. The purpose of this review is to prove a relatively comprehensive list of all the algorithms in the literature, therefore as to prompt further inquiry.

Swarm intelligence, sometimes referred to as collective intelligence, is defined as the problem solving behavior that emerges from the interaction of private factors (e.g., bacteria, ants, termites, bees, spiders, fish, fowl) which communicate with other agents by acting on their local environments.

Particle swarm optimization applies this idea to the problem of finding an optimal solution to a given problem by a lookup through a (multi-dimensional) solution space. The initial set-up is a cloud of particles, each representing a possible solution to the problem. Each particle holds its own speed, which depends on its previous velocity (the inertial component), the tendency towards the past personal best position (the nostalgia component), and its proclivity towards a global neighborhood optimum or local neighborhood optimum (the social component). Particles thus move through a multidimensional space and eventually Converge towards a situation between the global best and their personal best. Particle swarm optimization algorithms have been applied to various optimization problems, and to unsupervised learning, game learning, and scheduling applications.

In the same vein, ant algorithms model the foraging behavior of ant colonies. To see the best route between the nest and a source of food, ants rely on indirect communication by putting down a pheromone trail on the path back to the nest if they found food, respectively following the concentration of pheromones if they are looking for food. Ant algorithms have been successfully applied to a mixture of combinatorial optimization problems over discrete search spaces.

III. Taxonomy of swarm intelligence

Swarm intelligence has a marked multidisciplinary character since systems with the above mentioned characteristics can be discovered in a diversity of fields. Research in swarm intelligence can be separated according to different standards which are discussed in brief in this section. Figure 1 shows the Swarm Intelligence Taxonomy.

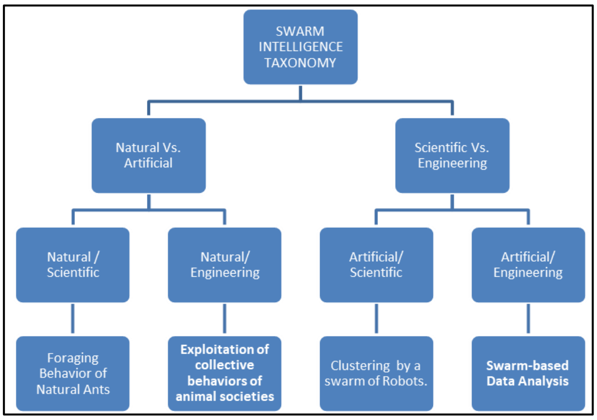

Fig. 1: Swarm Intelligence Taxonomy

A. Natural vs. Artificial

It is standard to separation swarm intelligence into two ranges, as per the way of the frameworks under examination. We talk in this manner of characteristic natural swarm intelligence examine, where organic frameworks are perused; and of artificial swarm knowledge, where human artifacts are considered.

B. Scientific vs. Engineering

The objective of the scientific stream is to model swarm intelligent system and to single out and translate the components that enable a framework all in all to carry on in a coordinated manner as a consequence of local individual-individual and individual-environment interactions. On the other hand, the goal of the engineering stream is to exploit the understanding developed by the science stream in order to design systems that are able to solve problems of practical relevance.

The two dichotomies natural/artificial and scientific/ engineering are orthogonal: although the typical scientific investigation concerns natural systems and the typical engineering application concerns the evolution of an artificial system, a number of swarm intelligence studies have been performed with swarms of robots for validating mathematical models of biological organizations. These studies definitely of a merely speculative nature and belong in the scientific stream of swarm intelligence. On the other hand, one could influence or change the behavior of the somebodies in a biological swarm so that a new swarm-level behavior emerges that is somehow functional to the resolution of some project of practical interest. In this instance, although the system at hand is a natural one, the goals pursued are definitely those of an engineering application. In the following, an example is presented for each of the four possible events.

C. Natural/Scientific: Foraging Behavior of Ants

In a now classic experiment done in 1990, Deneubourg and his group showed that, when given the option between two routes of different length joining the nest to a food source, a colony of ants has a high chance to collectively take the shorter one. Deneubourg has shown that this behavior can be explained via a simple probabilistic model in which each ant decides where to live by getting hold of random decisions based on the intensity of pheromone perceived on the dry land, the pheromone being deposited by the ants while moving from the nest to the food source and back.

D. Artificial/Scientific: Clustering by a Swarm of Robots

Several ant species cluster corpses to form cemeteries. Deneubourg et al. (1991) were among the first to offer a distributed probabilistic model to explain this clustering behavior. In their example, ants pick up and throw items with probabilities that depend on the information on corpse density which is locally available to the ants. Beckers et al. (1994) have programmed a group of robots to enforce a similar clustering behavior demonstrating in this way one of the first swarm intelligence scientific oriented studies in which artificial agents were employed.

E. Natural/Engineering: Exploitation of collective behaviors of animal orders

A possible development of swarm intelligence is the controlled development of the collective behavior of animal orders. No lesson is available in this field of swarm intelligence, although some promising research is currently in progress: For example, in the Leurre project, small insect-like robots are used as lures to influence the conduct of a group of roaches. The technology developed within this project could be applied to various fields including agriculture and cattle raising.

F. Artificial/Engineering: Swarm-based Data Analysis

Engineers have used the examples of the clustering behavior of ants as an inspiration for designing data mining algorithms. Further work was carried out by Lumer and Faieta in 1994. They defined an artificial environment in which artificial ants pick up and drop data items with probabilities that are ordered by the similarities of other data items already present in their vicinity. The same algorithm has also been applied for solving combinatorial optimization problems reformulated as clustering problems (Bonabeau et al. 1999).

Various Swarm Intelligence Algorithms are discussed in detail:

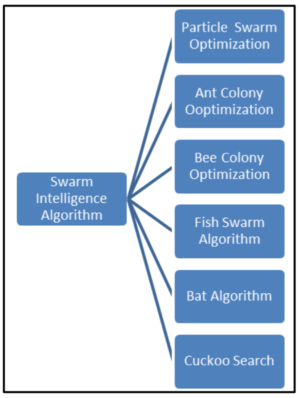

Fig. 2: Various optimization algorithm which falls under Swarm Intelligence Algorithm

G. Particle swarm optimization (PSO)

PSO algorithm is based on population based optimization technique proposed by Kennedy and Eberhart [20]. Due to its simple concept, efficient computation, easy implementation and unique searching mechanism PSO have been used in many engineering problems.

The steps of PSO are as below:

1) The swarm has to be initialized by specifying a random position.
2) Fitness function has to be computed for each molecule.

3) Compare the particle‘s fitness value with best for each individual particle. If the current value is better than the best value, then specify this as best for current particle‘s position.
4) The molecule is identified which has best fitness value and is identified as best.
5) Velocities and positions of all the particles are revised using step 1 and 2.
6) Until sufficiently good fitness value is achieved repeat steps 2-5.

H. Ant Colony Optimization (ACO)

Ant Colony Optimization (ACO) in the nineties Dorigo et al. (1996) named Ant System‖ (AS), the first ant algorithm, tested successfully on the Travelling Salesman Problem. To generalize, the overall method of solving combinatorial problems by estimated solutions based on the generic behavior of natural ants, The ACO meta heuristic was developed (Dorigo & Di Caro, 1999;) the three main functions of ACO is as follows. Ant Solutions Construct: this performs the construction process of solution where, according to a transition rule the artificial ants move through adjacent states of a problem, iteratively building solutions. Pheromone Update: This performs updating of pheromone trail. Updating the pheromone trails is done, once complete solutions have been instituted, or updating after each iteration. In addition to pheromone trail reinforcement, the ACO also includes pheromone trail evaporation. Evaporation of the pheromone trials helps ants to forget bad solutions that were defined early in the algorithm.

Daemon Actions: is the optional step in the algorithm that calls for applying extra updates from a worldwide perspective. This may include applying supplementary pheromone reinforcement to the best solution generated. To improve the performance of any system, Dorigo and Gambardella (1997) proposed an alternative approach, ant colony system (ACS), which is based on four modifications to ant system: a different transition rule, a different pheromone trail update rule, the role of local updates of pheromone trail to favor exploration, and the mapping of candidate list to limit the choice.

I. Bee Colony Optimization (BCO)

It is another Swarm Intelligence (SI) algorithm where the elements of the group are honey bees. Bees communicate with each other by a mechanism called ―Waggle Dance‖. They exchange information among themselves regarding the rich food source location. Because of their collective food foraging behavior, the name (BCO) is conveyed to the honey Bees. The bee system is a stock example of organized team work, labor division, simultaneous task performance, specialized individuals. There are different cases of honey bees. Each honey bee colony has a single queen bee. There is a queen bee, male drone bees and thousands of worker bees.
Several types of bees:

1) Queen

The responsibility of the Queen‘s is to lay eggs to form new colonies. The responsibility of Drones, which are the male of the hive is to match with the Queen Bee. It will be cast away from the colony during their fall. The worker bees are the females of the hive. They are the important building blocks of the hive. They are responsible for building the honey bee comb, cleaning it, maintain it, guard it, and feed the queen and drones. Apart from these, the principal job of the worker bee is to search and collect the food. Two examples of worker bees are there namely scouting bees and forager bees. Both of them are equally responsible for the accumulation of food, but with different roles. The character of Scout Bee‘s is to fly every which way all around and hunt for food. They go back to their hive after their exhaustion of energy and space boundaries. Upon arrival to their hive the scout bee shares their experience and a bunch of important information with the forager bees.

J. Artificial Bee Colony Algorithm (ABC)

Various swarm intelligence algorithms are available Based on the conduct of the bees in nature that are classed into two methods; foraging behavior and mating behavior. Algorithms simulating the foraging behavior of the bees include the Artificial Bee Colony (ABC), the Virtual Bee algorithm, the Bee Colony Optimization algorithm, the Bee Hive algorithm, the Bee Swarm Optimization algorithm. and the Bees algorithm. An individual entity demonstrates a simple set of behavior policies, just a group of entities shows complex emergent behavior with useful properties such as scalability and adaptability. Artificial Bee Colony is a predominant algorithm simulating the intelligent foraging behavior of a honeybee swarm, proposed by Karaboga and Basturk[19]. In ABC algorithm, the colony of artificial bees contains three groups of bees: employed bees, onlookers and scouts. An employed bee produces a change of the carriage in the memory depending on the local information and tests the nectar amount of the new source. Using the nectar amount of the new one is loftier than the previous one, the bees remember the rude one and forget the old single. Later on, every working bees complete the search procedure. They divvy up the nectar information on the food sources and their location information with the onlooker best in the dance field. The algorithm, global search performance depends on random search process performed by scouts and solution production mechanism performed by employees and onlooker bees.

K. Fish Swarm Algorithm (FSA):

FSA technique proposed by Li et al in 2002[18], which is inspired by the natural schooling behavior of fish

"The fish swarm calculation (FSA) is a populace based/swarm keen system that is breathed in by the normal tutoring conduct of fish.” FSA exhibits a strapping ability to avoid local minimums in order to achieve global optimization. In this algorithm fish is rendered by its D-dimensional position Xi = (x1, x2. . . xk, . . ., xD), and FSi to represent the food satisfaction for the fish. Euclidean distance dij = ‖Xi −Xj‖ denotes the relationship between two fish. FSA typically imitates three behaviors, which is specified as ― searching God, ― swarming in response to a threat, and ― following to boost the probability of achieving a flourishing result. Searching can be sounded out as as a random search adopted by fish for searching for food, with an inclination towards food concentration. The main objective is to minimize FS (food satisfaction).

1) Swarming

This aims at satisfying food ingestion needs, entertaining and attracting new swarm members. A fish which is bent up at Xi and has its neighbors within its visual Where Xc identifies the center position of those neighbors and it is used to identify the attributes of the entire neighboring swarm. If the swarm center has greater attentiveness of food than is usable at the fishes current position Xi (i.e., FSc < FSi), and if the swarm (Xc) is not very crowded (NS/n < δ), the fish will move from Xi to next Xi+1, toward Xc Following behavior is one, when a fish locates food, all neighboring individuals follow it. Within a fishes visual, few fish will be apparent as finding a greater measure of food than others, and this fish will obviously attempt to perplex with the best one (Xmin) in order to increase satisfaction (i.e., gain relatively more food [FSmin < FSi] and less crowding [NF/n < δ]).NF stands for the act of fish within the visual of Xmin. Three important parameters involved in FSA include visual distance (visual), maximum step length (amount), and a crowd factor. These two genes influence the effectiveness of FSA.

L. F. Bat algorithm (BA)

In 2010 yang [15] proposed Bat Algorithm which is also a swarm based metaheuristic algorithm inspired by a property called as echolocation. This echolocation is a type of sonar which guides bats during flying and hunting behavior. Two components which affect the search characteristics of an algorithm are exploration and exploitation. Exploration is nothing but a capability of an algorithm to regulate a result which is promising by seeking strange region, whereas the exploitation improves the result obtained by exploring. In survey many studies suggest that exploration capability of an algorithm must be applied first, and from which algorithm scans the whole search space and to improve the solution obtained by exploration should be utilized in the optimization process.

M. Cuckoo Search (CS)

CS is an optimization algorithm which was developed by Xian-She Yang and Suash Deb in the year 2009[21]. This CS algorithm was inspired by the obligate brood presentation of the cuckoo species which lays their eggs in the nests of other host birds. Some host birds engages direct conflict with the intruding cuckoos. For example, if the host birds discover that the eggs in their nests are not their own eggs, then they will either accept the alien eggs away or contribute up their nests and just show some other individual. The female parasitic cuckoos of New World brood-parasitic tapers are very narrowed down in the mimicry in colors and pattern of eggs which resembles the eggs of the chosen host species. Cuckoo search idealized such breeding behavior and thought of using this idea for various optimization problems. This idea can outperform other metaheuristic algorithm which is in applications. Cuckoo search uses the following representation.

1) Each egg in a nest is solved, and a cuckoo egg is a new solution. The purpose of CS is to replace the not so good solutions in the nests with the new solutions (cuckoo).Today, this algorithm is like each nest has one egg. But this algorithm can be extended such that each nest has multiple eggs which means multiplication.
2) The idealization rule of CS is based on, each cuckoo lays one egg at a time, and dumps in random nests.
3) The best nests with high quality egg will be carried to next generation The egg laid by a cuckoo is considered by the host bird with a probability of a pain(0,1). Discovering operate on some set of worst nests, and discovered solutions is dumped from further deliberations.

Let us focus on the advantages and disadvantages of the most hyped optimizing algorithm:

Algorithm	Advantages	Disadvantages	Application
Ant Colony Optimization	– Inherent Parallelism – Rapidly discover good solutions with positive feedback. – Efficient for small no. of nodes – Guaranteed convergence	– Difficult in theoretical analysis – Random decisions Change in – Probability distribution by iteration	– Water irrigation grids – GPS geodetic grids optimization Allocation of data in super computer.
Particle Swarm Optimization	– Easy to Perform – Small no. of Parameters to adjust – High efficiency in global searching	– Convergence is slow at redefined search stage – Weak in local search – Cannot work with non-coordinate system	– Human tumor analysis – Pressure vessel – Real time training of neural networks.
Genetic Algorithm	– Optimization problems are solved with multiple solutions. – Large no. of solution set can be quickly scanned. – Non parametrical, multidimensional, non-continuous, non-differential problems can be solved	– No Guarantee to give global optimum. – Don't assure for constant optimization response time. – Cannot use in dynamic problem – Limited to real time system application due to convergence and random solutions.	– State Assignment Problem (similar to TSP) – Economics – Scheduling – Computer Aided design – Etc.

Table 1: Advantages, Disadvantages & Application of ACO, PSO & Genetic Algorithm

IV. COMPARATIVE STUDY

A. ACO vs PSO

Ant Colony Optimization	Particle Swarm Optimization
Interaction among various ants is done through environment (adaptable).	Communication in PSO is direct (not adaptable).
It was designed to solve discrete optimization problem but later modified for continuous problem.	It was designed to solve continuous problem initially but later modified for discrete or binary optimization problems.
Solution space is construction graph (Weighted graph)	Solution space is set of n – dimensional points.

Table 2: ACO vs PSO

B. GA vs ACO

Genetic Algorithm	***Ant Colony Optimization***
Solves problem even when there no predefined shape, size & complexity.	It requires predefined and specific, source and destination.
It works locally with stable system , hence it suffers in unstable system	It uses the idea of self-organizing principles, hence it is suitable for dynamic or unstable problem.
Was designed to solve discrete problems.	It was designed to solve discrete optimization problem but later modified for continuous problem.

Table 3: GA vs ACO

C. GA vs PSO

Genetic Algorithm	Particle Swarm Optimization
Genetic was designed for discrete optimization where bit 0's & 1's are used.	PSO was designed for continuous problem and can choose any value to encode design variables.
Genetic consist of systematic steps of calculation in order to solve the problem.	It do not have any calculation method that can be considered systematical foundation.
It requires ranking of solutions	It does not require ranking of solutions.
It have exponential influence of population size on solution time.	It have linear influence of population size on solution time.
Ability to reach good solution without local search is less.	It have more ability to reach good solution without local search.
Tendency for premature convergence is medium.	Tendency for premature convergence is high.

Table 4: GA vs PSO

V. CONCLUSION

The detailed study on various nature inspired algorithm for optimization shows that it makes use of top down approach. Moreover, the processing of nature inspired algorithm is successive and repeated. The nature inspired model of computation, discussed in paper, shows the various algorithmic branch. Among those the focus of study was kept on swarm intelligence. Hence, the detailed study of various swarm intelligence algorithm and the comparative study of most hyped algorithms is done.

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