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Swarm Intelligence Algorithms - A Survey

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***Abstract*—** Swarm intelligence is an exploration ground that simulates the mutual behavior in groups of insects or animals. Some algorithms ascending from such models have been proposed to solve a widespread range of difficult optimization problems. Typical swarm intelligence algorithms including Particle Swarm Optimization (PSO), Ant Colony System (ACS), Honey bee mating optimization (HBMO), Bacteria Foraging (BF), the Artificial Bee Colony (ABC), Bat algorithm (BA), and Firefly algorithm, have been proven to be noble methods to address difficult optimization problems under static environments. Maximum SI algorithms have been established to discourse static optimization problems and hence, they can meet on the optimum solution powerfully. Swarm intelligence (SI) is built based on the combined characteristics of self-systematized systems. Furthermore the uses to conventional optimization problems, SI can also be used in monitoring robots and automated vehicles, forecasting social behaviors, improving the telecommunication and computer networks, etc. To be precise, the usage of swarm optimization can be applied to the various fields in engineering.

***Keywords*—** Particle Swarm Optimization (PSO), Ant Colony System (ACS), Honey bee mating optimization (HBMO), Bacteria Foraging (BF), the Artificial Bee Colony (ABC), Bat algorithm (BA), Firefly algorithm

I. INTRODUCTION

People obtain a lot of knowledge from Mother Nature. Applying the similarity to organic systems with loads of individual swarms or personalities, we are capable of handling the tasks in the algorithm and application with optimization methods. In the present paper, we emphasis on the summary of few widespread swarm intelligence algorithms, which points out their concepts, and suggests some enrichments of the algorithms.

The promising collective intelligence of groups of simple agents is termed as Swarm intelligence. With the idea of swarm intelligence, the algorithms that are developed need to be flexible to both the internal and external changes, to be strong when few individuals fail, to be devolved and self-organized. The idea is engaged in work on artificial intelligence.

Maximum SI algorithms have been established to discourse static optimization problems and hence, they can meet on the optimum solution powerfully. However, most of the real world problems have a vibrant environment that fluctuates over time. This paper presents a wider review on SI algorithms and gives a study of pros and cons of swarm algorithms. [1][2]

Rest of the paper is organized as follows, Section I contains the introduction of swarm algorithms. Section II contain the different swarm algorithms. Section III contain the pros of swarm algorithms. Section IV contain the cons of swarm algorithms. Section V concludes research work with future directions.

II. DIFFERENT SWARM ALGORITHMS

The different types of swarm intelligent algorithms are listed and described below:

A. Ant Colony Optimization (ACO)

ACO is motivated by the searching behavior of real ants. Finding the shortest path between their nest and food sources is the goal of ants. ACO is based on numerous building steps and on a dynamic memory structure that encloses evidence about the quality of formerly achieved results. Each ant signifies a probable key solution to the problem. ACO contains a forward approach where ants build their results based on the existing pheromone marks and experimental information available. Once all the ants are done with their forward mode they will shift to their backward mode where a shared pheromone counter is updated accordingly, i.e., as the solution quality increases, the more pheromone gets deposited. There are two main ACO perspectives which are evaporation based and population based. Their difference between them lies in the way how pheromone is deposited. The evaporation based perspective works by dropping the pheromone trails gradually by a constant quantity to eliminate any former old "decisions". The population based perspective works by using a population which will remove pheromone trails directly when a solution is deleted from the population as in figure1. The algorithm is given below [3].

Begin
Initialize the pheromone trails and parameters;
Generate population of m solutions (ants);
For each individual ant k € m: calculate fitness (k);
Determine the best global ant;
Update the pheromone trail;
Check if termination = true;
End;

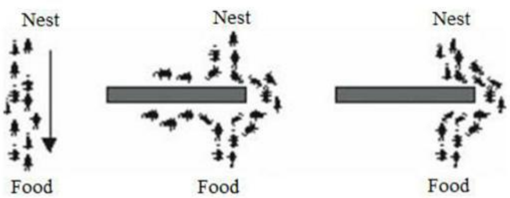

Figure 1: Ant's behavior to find the shortest path between the food and nest.

Advantage: Ant colony algorithm shows strong robustness which has the ability to search for a better solution. Ant colony algorithm is a population-based algorithm which is easy for the parallel implementation. Ant colony algorithm contributes slowly and easily falls into local optimum. [4]

B. Particle Swarm Optimization (PSO)

PSO was first offered for addressing the continuous optimization problems. Here each particle denotes the possible solution. More accurately, each particle will include a velocity and position vectors, which are updated according to the best so far position of particle and of the swarm as well, respectively.

The global best and the local best, are the two chief models of PSO algorithm. The neighbourhood structure for each particle in both the models differs from each other. In the global best model, the neighbourhood of a particle comprises the particles in the entire swarm, which share the information among each other. Whereas, in the local best model, the neighbourhood of each particle is well-defined by several fixed particles. Due to their characteristics, both models are used in different ways. The local best model is usually used in algorithms with a single swarm, where the global best model is usually used in multi-swarm based algorithms [5]. The algorithm is given below.

a) **for** each particle $i = 1, ..., S$ **do**
b) Initialize the particle's position with a uniformly distributed random vector: $\mathbf{x}_i \sim U(\mathbf{b}_{lo}, \mathbf{b}_{up})$
c) Initialize the particle's best known position to its initial position: $\mathbf{p}_i \leftarrow \mathbf{x}_i$
d) **if** $f(\mathbf{p}_i) < f(\mathbf{g})$ **then**
e) update the swarm's best known position: $\mathbf{g} \leftarrow \mathbf{p}_i$
f) Initialize the particle's velocity: $\mathbf{v}_i \sim U(-|\mathbf{b}_{up}-\mathbf{b}_{lo}|, |\mathbf{b}_{up}-\mathbf{b}_{lo}|)$
g) **while** a termination criterion is not met **do**:
h) **for** each particle $i = 1, ..., S$ **do**
i) **for** each dimension $d = 1, ..., n$ **do**
  i. Pick random numbers: $r_p, r_g \sim U(0,1)$
  ii. Update the particle's velocity: $\mathbf{v}_{i,d} \leftarrow \omega\, \mathbf{v}_{i,d} + \varphi_p\, r_p\, (\mathbf{p}_{i,d}-\mathbf{x}_{i,d}) + \varphi_g\, r_g\, (\mathbf{g}_d-\mathbf{x}_{i,d})$
j) Update the particle's position: $\mathbf{x}_i \leftarrow \mathbf{x}_i + \mathbf{v}_i$
k) **if** $f(\mathbf{x}_i) < f(\mathbf{p}_i)$ **then**
  i. Update the particle's best known position: $\mathbf{p}_i \leftarrow \mathbf{x}_i$
  ii. **if** $f(\mathbf{p}_i) < f(\mathbf{g})$ **then**
  iii. Update the swarm's best known position: $\mathbf{g} \leftarrow \mathbf{p}_i$

Advantage: Particle swarm optimization is the algorithm that can be implemented easily. The principle used behind the particle swarm optimization is very simple. The algorithm has limited number of parameters and its application effect is obvious. It is mainly used to handle non-linear optimization problems, non-differentiable and complex multi- peak function. [4]

C. Artificial Bee Colony (ABC)

An ABC algorithm will imitate the actions of real bees groups. An orthodox ABC algorithm comprises of food sources, where each food source denotes a probable solution for the problem. There are three groups of bees like employed, onlooker and scout. These bees will update the food sources. Within the employed bee phase, bees will search for new solutions. In precise, each bee will produce a new candidate food source position from the older one. In case the food sources with more nectar are detected, it means, the new solutions will have better fitness than the current, then they will be updated. Next, the qualified chances according to the fitness determined from the employed bee phase are determined in the onlooker bee phase. Then, the onlooker bees choose a solution in which the fittest solutions will have a higher probability that are to be selected by onlooker bees. After that, onlooker bees will have the same behavior with the employed bees. Finally, scout bees randomly reallocate solutions in case they are uncontrolled, e.g., if they have not been updated for a definite time [6]. The algorithm is given below.

a) Send the scouts onto the initial food sources
b) Repeat
  i. Send the employed bees onto the food sources and determine their nectar amounts
  ii. Calculate the probability value of the sources with which they are preferred by the onlooker bees

iii. Send the onlooker bees onto the food sources and determine their nectar amounts
iv. Stop the exploitation process of the sources exhausted by the bees
v. Send the scouts into the search area for discovering new food sources randomly
vi. Memorize the best food source found so far
c) Until (requirements are met)

Advantage: The major advantages which ABC holds well are: Simplicity, flexibility and robustness. The algorithm has limited control parameters compared to other search techniques. It has easy hybridization when compared to the other optimization algorithms. It has the ability to handle the objective cost with stochastic nature. It is easy for the implementation with basic mathematical and logical operations [7].

D. Bacterial Foraging Optimization (BFO)

The BFO algorithm is motivated by the compound organized activities in bacterial scavenging and the existence of bacteria in different environments. A BFO algorithm involves numerous bacteria. These bacteria will help in signifying the solutions in the optimization problem. The BFO algorithm comprises of three processes: chemotaxis, reproduction, and elimination dispersal. In chemotaxis, a bacteria with random direction symbolizes a fall and a bacteria with the same direction of the previous step specifies a run.

In the reproduction process, all bacteria is sorted and only half of the suitable bacteria survive. Later, the surviving bacteria is fragmented into two indistinguishable ones to form the new bacteria. Lastly, in the elimination-dispersion process, a bacteria is selected to move to an altered random location in the search space. Though this act maintains the assortment during execution, it may interrupt the optimization process and hence it is performed after several steps of the reproduction method [7] [8].

E. Artificial Fish Swarm Optimization (AFSO)

There are numerous existing developments of fish-inspired algorithms. Within AFSO, each artificial fish searches for a position which has more food source (better fitness). Each fish search food by carrying out three main behaviours: prey, swarm and follow. The prey behavior is performed by an artificial fish without considering other swarm members. More precisely, a fish finds the target position which is better than the current. The swarm behavior is a collective behavior of all the fishes and is performed globally among all members of swarm. Each artificial fish consists of a number of neighbours within its visual. In case the central position of the visual field is found to be better; then it moves towards the central position; otherwise, the prey behavior is performed again.

Similarly, the follow behavior is performed, but instead of moving toward the central position, the artificial fish will move toward a better neighbour position within its visual. Otherwise, the prey behavior is performed again. Basically, the prey behavior is performed when an artificial fish is not able to move to a better position when follow or swarm behavior are performed. In case the algorithm reaches stagnation behavior some artificial fishes are selected randomly from the whole artificial fish swarm and are set randomly. The best so far artificial fish position (i.e., solution) is recorded [8].

F. Firefly Algorithm (FA)

The FA was inspired by the flashing patterns and behavior of fireflies. An FA is based on three assumptions:
1. All fireflies can be attracted by all other fireflies
2. The attractiveness or magnetism of each firefly is proportional to the brightness of other fireflies
3. The background of the problem determines the brightness of fireflies.

Hence, a firefly which has lesser brightness will move towards a brighter one. Otherwise, if a firefly is not able to locate any brighter firefly, it moves randomly. Each firefly will glow proportionally to its solution quality. The bees with better solution quality together with its attractiveness, detects how strongly it attracts other members of the swarm [9]. The algorithm is given below.

Begin
1) Objective function: f(x), x = (x_1, x_2, $x_{3......}$,x_d)
2) Generate an initial population of fireflies x_i (i=1,2,….n)
3) Formulate light intensity I so that it is associated with f(x) (for example, for maximization problems, I α f(x) or simply I = f(x))
4) Define absorption coefficient, γ
While (t < MaxGeneration)
for i = 1 : n (all n fireflies)
for j = 1 : n (n fireflies)
if ($I_j > I_i$),
Vary attractiveness with distance r via exp(-γ r);
move firefly i towards j;
Evaluate new solutions and update light intensity;
end if
end for j
end for i
Rank fireflies and find the current best;
end while
Post-processing the results and visualization;
End;

Advantage: Firefly algorithm can enhance the unimodal function and find the global optimal solution. It can enhance not only the unimodal but it also optimizes multimodal function and find numerous local optima. Firefly optimization algorithm is easy to operate and also to implement. It has less number of parameters, for the algorithm.

G. Honey Bee Mating Optimization (HBMO)

A Honey-Bees Mating Optimization (HBMO) algorithm may be constructed with the following five main stages:
1. The algorithm starts with the mating–flight, where a queen (best solution) selects drones probabilistically to form the list of drones. A drone is then selected from the list at random for the creation of broods.
2. Creation of new broods (trial solutions) by cross overring the drones' genotypes with the queen's.
3. Use of workers (heuristics) to conduct local search on broods (trial solutions).
4. Adaptation of workers' fitness based on the amount of improvement achieved on broods.
5. Replacement of weaker queens by fitter broods [10].

H. Bat Algorithm (BA)

The Bat algorithm (BA) is a nature-inspired algorithm, which has just been applied in many applications. BA can deal with both continuous optimization and discrete optimization problems. One of the major advantages is that BA can deliver very quick convergence at the initial stage and can automatically shift from exploration to exploitation when the optimality is upcoming. The main characteristics in the BA are based on the echolocation behavior of microbats. As BA uses frequency tuning, it is in fact the first algorithm of its kind in the context of optimization and computational intelligence. Each bat is encoded with a velocity vit and a location xit, at iteration t, in a d-dimensional search or solution space. The location can be considered as a solution vector to a problem of interest. Among the n bats in the population, the current best solution x∗ found so far can be archived during the iterative search process [11].

III. PROS OF SWARM ALGORITHMS

There are few advantages of using swarm algorithms. They are described below.

A. Scalability:

SI systems are said to be highly scalable because their inspiring skills are maintained when using groups ranging from just few individuals up to the millions of individuals. In other words, the control mechanisms used in SI systems are not too dependent on swarm size, as long as it is not too small.

B. Adaptability:

SI Systems make use of their inherited auto-configuration and self-organization capabilities. This helps them in responding well to rapidly changing environments. This allows them to freely adapt their individuals 'behaviour to the external environment dynamically on the run-time, with significant flexibility.

C. Collective Robustness:

As the SI Systems cordially work without any central control, the systems are robust. As a result, there is no single individual vital for the swarm to continue to the function. In other words, the fault tolerance capability of SI systems is remarkably high, since these systems have no single point of failure. A single point of failure is a part of any system that puts the entire system into risk of a complete failure, if it ceased to function.

IV. CONS OF SWARM ALGORITHMS

There are few disadvantages of using swarm algorithms. They are described below.

A. Time-Critical Applications:

The SI systems have their pathways to solutions. But the pathways are neither predefined nor pre-programmed, but they are emergent. Hence, SI systems are not appropriate for time-critical applications which require on-line control of systems and time critical decisions. It is useful, only for non-time critical applications that involve numerous repetitions of the same activity.

B. Parameter Tuning:

Tuning the parameters of SI-motivated optimization techniques is one of the general drawbacks of swarm intelligence. Many parameters of SI systems are problem-dependent, so they are either i) pre-selected based on the problem characteristics using a trial-and-error method, or ii) even better flexibly adapted on run time. Ex PSO

C. Stagnation:

Because of the lack of central coordination, SI systems could suffer from a stagnation situation or a premature convergence to a local optimum for e.g., in ACO, stagnation occurs when all the ants ultimately follow the same suboptimal path and construct the same path. This limitation, can be controlled by setting algorithm parameters carefully.

V. CONCLUSION

Swarm intelligence studies the collective behaviors in a group of individuals. It has shown momentous accomplishments on solving large scale, dynamical, and multi-objective problems. With the application of the swarm intelligence, more quick and effective methods can be planned to solve big data analytics problems. This paper presented different swarm intelligence schemes that are Particle Swarm Optimization (PSO), Ant Colony System (ACS), the Artificial Bee Colony (ABC), Bacterial Foraging Optimization (BFO), Artificial Fish Swarm Optimization (AFSO), Bat Algorithm (BA) and Honey Bee Matting Optimization (HBMO), which are good methods to address difficult optimization problems under stationary environments. The pros and cons of Swarm algorithms is also explained.

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