Autonomous Swarm Intelligence

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Abstract- This paper provides an overview of the science behind swarm intelligence. Some examples of swarm which we encounter in our day to day life. A biological approach to swarm by discussing ant colony optimization algorithm and its applications. The survey also throws light on particle swarm optimization algorithm and its limitations.
Keywords- metaheuristic optimization, Particle, swarm, fitness, Intelligence

I. INTRODUCTION

We live in a digital era where the complexity of operational scenarios is extension, heterogeneity and uncertainties in any environment. Every living organism exists in clusters and colonies, from the very basic unit of life considering the cell to the complex species such as fishes, birds and other animals . They exhibit properties such as self-organization in coordination, decision making, and social coherence. These characteristics have a direct impact on the environmental facet, communication, leadership and much such specialized individual behavior where biological researchers had their focal point on identifying and observing their capability to react and reorganize to the innate behavioral style of the living organisms. We address a group of organisms together, such as a colony of ants, a swarm of bees or even a school of fish and look into the intricate details of how they organize themselves. These biological inspirations served as the root of a new science known as the swarm intelligence.

Swarm intelligence comes from swarming behavior of groups of organisms. Being in a group allows them to solve difficult or impossible problems for a single individual to achieve or surpass such cognitive limitations. Swarm Intelligence is being constituted to perceive the biological and artificial angles of these complex processes in the organisms. Ant colony optimization is an algorithm to search and find the optimum path from the food source to the nest based on the behavior of the ants, ACO is a metaheuristic inspired algorithm which simulates the biological behavior of the ants. Ants mark their best solutions and take account of previous markings to optimize their search.

Particle swarm optimization is relatively another prime algorithm in swarm intelligence where every individual shares its knowledge by providing its optimal solution in terms of personal best, team best and current status. This algorithm was inspired by mimicking the behaviour of birds and fishes. PSO is a robust stochastic optimization technique. In PSO, a swarm of n particles (individuals) communicate either directly or indirectly with one another using search directions (gradients).

The rest of the paper is organized as follows. Proposed embedding and extraction algorithms are explained in section II. Experimental results are presented in section III. Concluding remarks are given in section IV.

II. ANT COLONY OPTIMIZATION

2.1 Inspiration from Ants

Ants are the most abundantly found living organism, they always work in groups. It is a prime example for a working swarm. If we view them independently, each of them are very simple and are almost blind, but together they achieve complex tasks. Ant behavior was the inspiration for the metaheuristic optimization technique.

Ants exhibit stigmergy which is an indirect means of communication by making use of pheromones. The term “pheromone” is derived from a Greek word Pherin that means 'to carry’ and ‘(hor)mone’ which means to stimulate. It is a volatile chemical substance which is secreted from the body to impact the behavior of other ants.

There are different types of pheromones produced by ants depending on the situation-

- Alarm pheromone – This is produced when an ant is crushed which sends a signal to other ants that there is danger and to move away from the area.
- Food trail pheromone – The organism creates a pathway by secreting these pheromones from the food source to the nesting location, which influences other organisms to follow. The intensity of the pheromone released is higher where the probability of finding food is more [6] [8].

Ants are minute creatures which individually cannot achieve even simple tasks like finding shortest path for food source due to their intellectual limitations but collectively they are capable of achieving bigger tasks like building anthills and gathering and storing food. They divide their work among themselves and assign tasks to each other. It’s only then that they can perform efficiently in a co-operated manner to achieve the goals of their colony [7]

2.2 Ant Colony Optimization (AOC) Algorithm

Ants tend to choose the shortest path towards food based on the concentration of the pheromones. The Ant Colony Optimization (ACO) algorithm is a metaheuristic motivated from the ants in their hunt for the shortest path in finding food. The algorithm simulates the biological behavior of ants including the mechanism of cooperation, adaptation and exploration [7].

The ACO algorithm is used to resolve highly composite, combinatorial optimization and distributive issues like vehicle routing, internet routing, travelling salesman problem, quadratic assignment problems, antennas optimization, device sizing, data mining, protein folding and to solve complex problems in nature [9].

The ACO is used in swarm intelligence which is inspired from the foraging behavior of ants. The ACO algorithm is composed of numerous cycles/iterations for a solution as in the Fig. 1. In each iteration, many ants together build a proper solution using heuristic information and accumulated experiences of antecedent groups of ants [11].

Since the time ACO was introduced various variations and optimizations were done to the original algorithms. The complete foraging process is as follows :

- Individual ant explores the environment randomly in search of food.
- They perceive the pheromone strength at that place.
- When food is found, they return back to the nest and on the way leave pheromone markers.
- Other ants sense these markers and follow the track.
- These new ants decide to deploy the pheromone and increase pheromone thickness.
- More agents follow these markers.
- If shorter route is found, many follow the shorter route thereby increasing the pheromone thickness and concentration.
- If obstacle is encountered then agents move randomly until new shorter route is found.
- These stigmeric movements and foraging behavior as shown in Fig.2 demonstrate the following concepts:
- Self-coordinating conduct of the ants where the positive feedback is introduced when more number of ants follow the same route by increasing pheromone concentration.
- Due to evaporation/volatile behaviour of pheromones, the ants choose a new route if the pheromones have evaporated and negative feedback is introduced.

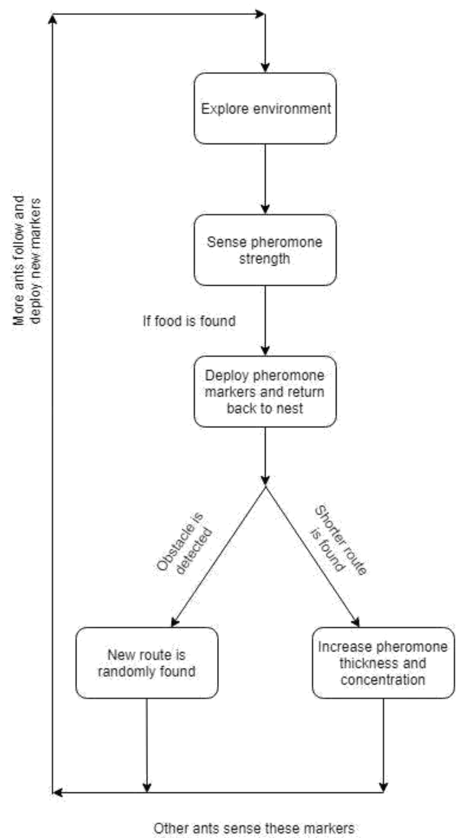

Figure 1. Flowchart depicting the foraging behavior of ants

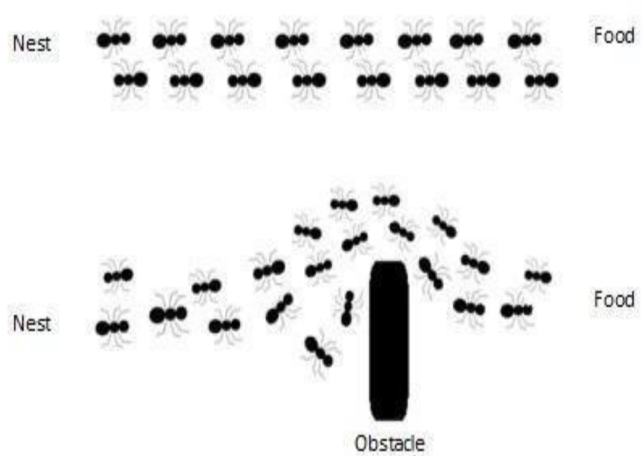

Figure 2. Stigmeric behavior to find the shortest path between food and nest

Algorithm: Ant Colony Optimization

Step 1: Initialize parameters

Position ants on different locations, initialize the intensity of the pheromones towards the ends. Set the first element of each ant’s tabu list to be its starting point.

Step 2: Schedule activities

Each ant is assigned certain specific tasks as to travel from point A(i) to point B(j) according to the probability p(i,j).

Step 3: Construct Solutions

After completing ‘n’ moves each ant has a complete tour, where the tabu list is full, so compute Lk (cost of kth ant’s tour) and $\Delta Tk(i,j)$ (amount of pheromone deposited by kth ant). Save the shortest path found and the empty the tabu lists.

Step 4: Local update of pheromones

Based on the solution obtained the pheromones strengths are updated locally with regard to a single ant.

Step 5: Global update of pheromones

The intensity of pheromones are updated globally with regard to all the ants within the colony.

Step 6: End scheduled activities

These sequential steps are iterated until the tour counter reaches maximum or until stagnation where all ants make the same tour.

III. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a nature-inspired evolutionary and stochastic optimization technique to solve computationally hard optimization problems. Particle Swarm Optimization (PSO) is an optimization algorithm pertaining to a folk of particles devised by Dr. Eberhart, Dr.Kennedy [1][2] in the year 1995. This algorithm was motivated by observing the social synergy of animals and birds [3].

PSO has been built by abstracting the working mechanism of natural phenomenon. This algorithm analyses as shown in Fig.3 the social behavior of birds and fishes involving group communication wherein each individual contributes by sharing its knowledge during activities like food search, migration, etc.

Of late this algorithm has gained fame because of its ease of implementation and other desirable properties like quick convergence, dimensionally scalable and so on.

3.1 PSO in Swarm Intelligence

In 1989 Gerardo Beni and Jing Wang were the first to in introduce the swarming behavior among cellular robot system. In PSO method, each individual in the swarm is termed as particle/candidate, wherein each particle represents a solution in search space.

The fitness function evaluates the fitness of each particle solution. The fitness values of every particle is measured and the particle with the best fitness is chosen as gBEST.

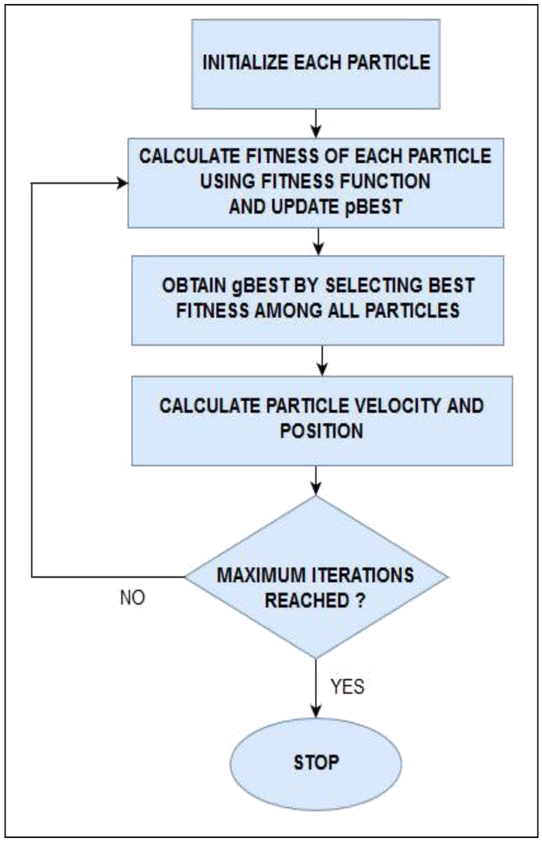

Figure 3. Flowchart of PSO Algorithm

Algorithm: Particle Swarm Optimization Algorithm

```
FOR each particle
   Initialize the particle
END
FOR each particle
   Calculate particle's fitness
   If current fitness value is better than pBEST, set current fitness value as pBEST
END
Select best fitness value among all the particles as gBEST
For each particle
   Calculate/Update particle's velocity using equation (1)
   Calculate/Update particle's position using equation (2)
```

The position and velocity of each particle is evaluated and updated using the formula:

$$v_i (t+1) = w\, v_i (t) + X \quad (1)$$

Where
X = (c1*rand()*(xipBEST-xi (t))+(c2*rand()*(gBEST-xi (t)))

xi (t+1) = xi (t) + vi (t+1) (2)

where xi is the present velocity of the ith particle, w is the inertia weight coefficient, c1 and c2 are acceleration coefficients for cognitive and social parameters, rand is a random value (0,1), xipBEST is particle's best known solution, xi is particle's present position, gBEST is the swarm's best known solution.

3.2 Advantages of PSO

1. PSO can be applied for both discrete as well as continuous functions since it is less affected by nature of the function.
2. Unlike Genetic Algorithm there are no crossover and mutation operators and also the particles update themselves with internal velocity.
3. Hybrid algorithms can be synthesized by incorporating other optimization techniques because of it flexibility.
4. The function evaluation is easy since it involves basic mathematical operations.
5. PSO is computationally efficient than Genetic Algorithm since it has faster performance and requires inexpensive time.
6. Function parameters can be easily adjusted since it has only less number of parameters.

3.3 Limitations

1. PSO has a tendency for premature convergence in mid optimum points.
2. It has a slow convergence in local search space.
3. This algorithm cannot be applied for scattering and optimization problems.
4. Also this approach cannot be used for solving problems of non-coordinate system.

IV. CONCLUSION

Swarm intelligence is a prominent concept in artificial intelligence and computer science with new properties emerging day by day. The core target of swarm intelligence algorithms is to enlist many such single agents(mediums) which do not have any restrictions, leads to an emergent global behavior. This global behavior is much stronger than the capabilities of the single agents, and applied algorithmically in studies of artificial intelligence could be vital in discovering very efficient methods of solving problems. Hence swarm intelligence has become an indispensable way to solve many subtle problems which we face in our day to day life.

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