Visualization of Ant Colony Optimization

A.V.Pavani[1], D.Naina[2],R.Nagendra Babu[3],N.Swarna Jyothi[4],S.Chinna Gopi[5]

[1]*Student, CSE, Vijaya Institute of Technology for Women, Andhra Pradesh, India,* ***atmakuripavani99@gmail.com***
[2]*Student, CSE, Vijaya Institute of Technology for Women, Andhra Pradesh, India,* ***naina.jenny22@gmail.com***
[3]*Assistant professor,Vijaya Institute of Technology for Women, Andhra Pradesh, India,* ***nrajaboina@yahoo.com***
[4]*Assistant professor,Vijaya Institute of Technology for Women, Andhra Pradesh, India,****swarnajyothi117@gmail.com***
[5]*Assistant professor,Vijaya Institute of Technology for Women, Andhra Pradesh, India,****simhadri594@gmail.com***

Abstract

The complex behaviors of social animals have been much studied and one of the behaviors is Swarm Intelligence. Swarm intelligence is typically made up of a population of simple agents interacting locally with one another and with their environment. IN this paper, we have discussed two techniques of swarm intelligence: Ant Colony Optimization (ACO) where ants communicate with each other using pheromone to find shortest paths and Particle Swarm Optimization(PSO) where it is used to optimize problems to provide candidate solutions using particles .Later we have provided details regarding the pheromone (chemical substance deposited by ants), various behaviors of ants such as foraging behavior ,Division of labour,brood sorting,co-operative sorting and their applications in real world.

Index Terms: *Agents, Shortest Path, Pheromone, Heuristic*

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1.SWARM INTELLIGENCE:

It is an artificial technique based on the study of collective self-organized systems. In other words: design of complex adaptive systems that do the job.

eg: Fish Schooling, birds flocking

2. TECHNIQUES OF SWARM INTELLIGENCE:

2.1 Particle Swarm Optimization (PSO)

In Computer-Science, particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position but, is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions.

PSO is originally attributed to Kennedy, Eberhart and Shiand was firstintended for simulating social behavioras a stylized representation of the movement of organisms in a bird flock or fish school. The algorithm was simplified and it was observed to be performing optimization. The book by Kennedy and Eberhart describes many philosophical aspects of PSO and swarm intelligence. An extensive survey of PSO applications is made by Poli.PSO is a metheuristic as it makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, metaheuristics such as PSO do not guarantee an optimal solution is ever found. More specifically, PSO does not use the gradient of the problem being optimized, which means PSO does not require that the optimization problem be differentiable as is required by classic optimization methods such as gradient descent and quasi-newton methods. PSO can therefore also be used on optimization problems that are partially irregular, noisy, change over time, etc.

Figure 1: collective behavior of fishes

The complex social behaviors of ants have been much studied, and computer scientists are now finding that these behavior patterns can provide models for solving difficult combinatorial optimization problems. The attempt to develop algorithms inspired by one aspect of ant behavior, the ability to find shortest paths, has become the field of ant colony optimization (ACO). The ant colony optimization algorithm (ACO), introduced by Marco Dario, in the year 1992, is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs.

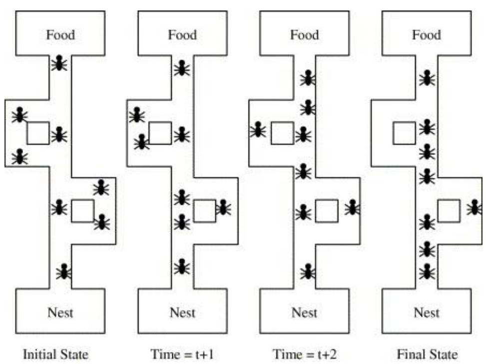

Figure2: Path to find food

3. DETAILS OF PHEROMONE

Ants communicate with each other using pheromones, sounds, and touch. The use of pheromones as chemical signals is more developed in ants than in other hymenopteran groups. Like other insects, ants perceive smells with their long, thin, and mobile antennae. The paired antennae provide information about the direction and intensity of scents. Since most ants live on the ground, they use the soil surface to leave pheromone trails that may be followed by other ants. In species that forage in groups, a forager that finds food marks a trail on the way back to the colony; this trail is followed by other ants, these ants then reinforce the trail when they head back with food to the colony. When the food source is exhausted, no new trails are marked by returning ants and the scent slowly dissipates. This behavior helps ants deal with changes in their environment. For instance, when an established path to a food source is blocked by an obstacle, the foragers leave the path to explore new routes. If an ant is successful, it leaves a new trail marking the shortest route on its return. Successful trails are followed by more ants, reinforcing better routes and gradually identifying the best path.

Ants use pheromones for more than just making trails. A crushed ant emits an alarm pheromone that sends nearby ants into attack frenzy and attracts more ants from farther away. Several ant species even use "propaganda pheromones" to confuse enemy ants and make them fight among themselves. Pheromones are produced by a wide range of structures including Dufour's glands, poison glands and glands on the hindgut, pygidium, rectum, sternum, and hind tibia. Pheromones also are exchanged, mixed with food, and passed by trophallaxis, transferring information within the colony. This allows other ants to detect what task group (e.g., foraging or nest maintenance) other colony members belong to. In ant species with queen castes, when the dominant queen stops producing a specific pheromone, workers begin to raise new queens in the colony.

Some ants produce sounds by stridulation, using the gaster segments and their mandibles. Sounds may be used to communicate with colony members or with other species.

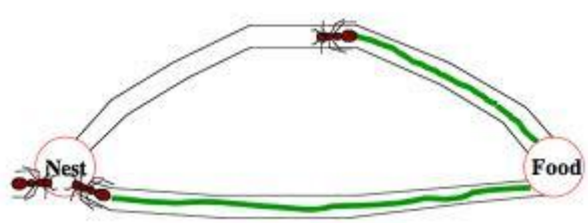

Figure 3: Presence of Pheromone

Pheromone information is used in Ant Colony Optimization (ACO) to guide the search process and to transfer knowledge from one iteration of the optimization algorithm to the next. Typically, in ACO all decisions that lead an ant to a good solution are considered as of equal importance and receive the same amount of pheromone from this ant (assuming the ant is allowed to update the pheromone information). Thus, the decisions of an ant do not have the same value for the optimization process and strong pheromone update should be prevented when competition is weak. We propose a measure for the strength of competition that is based on Kullback-Leibler distances. This measure is used to control the update of the pheromone information so that solutions components that correspond to decisions that were made under stronger competition receive more pheromone. We call this update procedure competition controlled pheromone update. The potential usefulness of competition controlled pheromone update is shown first on simple test problems for a deterministic model of ACO. Then we show how the new update method can be applied for ACO algorithms.

The successful techniques used by ant colonies have been studied in computer science and robotics to produce distributed and fault-tolerant systems for solving problems,for example Ant colony optimization and Ant-robotics. This area of biomimetic has led to studies of ant locomotion, search engines that make use of "foraging trails", fault-tolerant storage, and networking algorithms.

4. VARIOUS BEHAVIOURS OF ANTS

Several different aspects of behavior of ant colonies have inspired different kinds of **algorithms**.Examples are foraging,division of labor,brood sorting and cooperative transport**.**

4.1 Foraging Behavior:

Ants usually live in nests that can contain anywhere from a few dozen individuals to a few million. Food for the colony is provided by older ants who leave the nest to forage. Some species make foraging trails: long, tiny highways full of ants shuffling back and forth to bring food to the colony. These form when an ant returning with food lays down a special chemical (called a pheromone) on her way back to the nest; since the ants have a slight tendency to move towards the pheromone, they follow the chemical path and reinforce it, soon forming a trail. This shows how decisions made by individual ants (to follow the pheromone) can sum together to generate an overall behaviour that seems purposeful (forming a foraging trail). This kind of behaviour makes it possible for colonies to solve challenging problems, like finding the shortest path to food, without any kind of centralized planning or decision making.

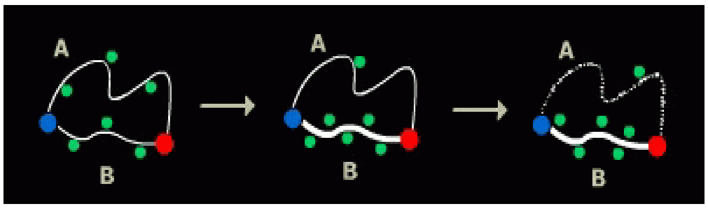

Figure 4: Pheromone Updation

Applications:

- Travelling Sales Man
- Graph colouring
- Logistics

4.2 Division of Labour:

Division of labour in ant societies is a kind of role model for distributed problem solving. They are so because ants are simple, non-cognitive, distributed and autonomous and yet they solve an optimization problem that is very complex and dynamic. This is very desirable in computer science, but as of yet not much research has gone into explaining the underlying mechanisms of division of labour by means of evolutionary algorithms, find the implications spatial constraints play in the division of labour in a foraging task of virtual ants. The ants differ only in size, and size implies constraints regarding to ease of movement in an environment where obstacles of other ants and clay exists. The results show that spatial constraints do play a major role in the job-task division evolved, in that test setup with increasing constraints exhibited division of labour in that ants of different sizes occupy different spatial areas of the task domain. In the process, we have evolved the behaviour of the ants that underlie the division of labour. This was done via mapping functions and motivation networks.

Applications:

- In group of robots
- organic computing systems

Brood Sorting:

Ant colonies sort their brood in concentric annuli with the smallest items in the middle and the largest on the periphery. Such brood sorting is a prime example of collective structure formation by social insects. We tested the hypothesis that broodsorting has two phases: the phase of clustering, proposed earlier, is followed by a phase of spacing, when ants move brood items away in a random direction but in a type-specific way so that items of different brood types spread out to a different extent. We hypothesized that in phase 2, spacing, items of the smallest brood type spread out the least and end up in the centre, whereas items of the largest brood type spread out the most and end up on the periphery. We found two distinct phases in the direction of brood movement during brood sorting associated with nest emigration. In phase 1, ants moved brood items in the direction away from the nest entrance. This was the clustering phase. In phase 2, ants moved brood items in a random direction. This was the spacing phase. Ants moved smaller items for longer than larger items. This is consistent with the hypothesis that ants put down brood items as a function of their weight. The diffusion coefficient and the frequency of movement were different for different brood types. The measure of the average spread (root-mean-square displacement) for each brood type was consistent with their order from the centre to the periphery of the sorted brood structure. The process underlying this spread, however, could not be simple diffusion since the movements of different brood types are interdependent.

Applications:

- Replication

4.3Cooperative sorting:

Ant colony system (ACS), a distributed algorithm that is applied to the traveling salesman problem (TSP). In ACS, a set of cooperating agents called ants cooperate to find good solutions to TSPs.Ants cooperate using an indirect form of communication mediated by pheromone they deposit on the edges of the TSP graph while building solutions. We study ACS by running experiments to understand its operation. The results show that ACS outperforms other nature-inspired algorithms such as simulated annealing and evolutionary computation, and we conclude comparing ACS-3-opt, a version of ACS augmented with a local search procedure, to some of the best performing algorithms for symmetric and asymmetric TSPs.

Applications:

- Box Pushing
- Stagnation Recovery
- Mass Effect

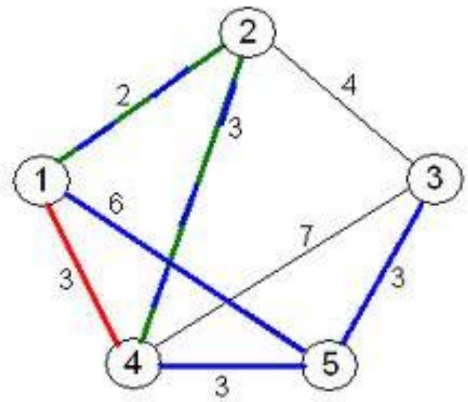

Figure 5:Shortest Path between Cities

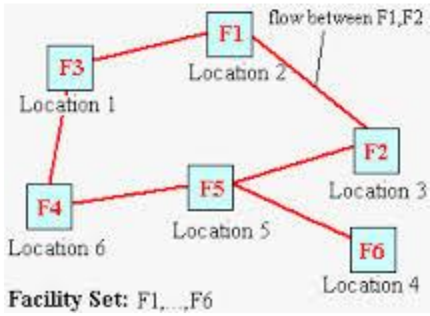

Figure 6:shortest Path using Quadratic Assignments

Applications of ACO algorithms:

- Travelling Salesman Problem
- Scheduling Problem
- Quadratic Assignments
- Sequential ordering
- Graph coloring
- Vehicle Routing

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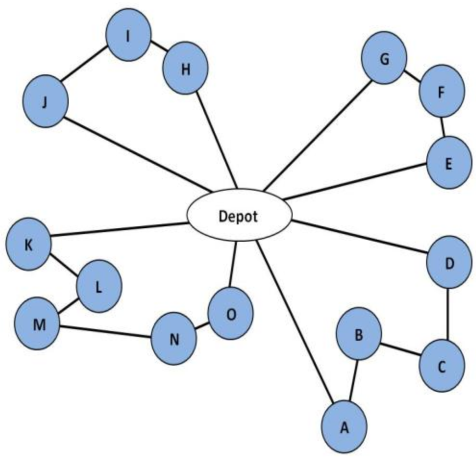

Figure 7:Shortest Path between vehicles

- Shortest Common Supersequence
- Frequency Assignment
- Generalised Assignment
- Multiple Knapsac
- Optical Network Routing
- Redundancy Allocation
- Constraint Satisfaction

5. CONCLUSION

Ant Colony Optimization has been and continues to be a fruitful paradigm for designing effective combinatorial optimization solution algorithms.Details regarding pheromone,various behaviours of ants helps us to clearly visualize ACO and its applications.The main motto behind this paper is to show the role of ants and make a clear understanding of how they provide optimal solutions in the field of ACO.

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BIOGRAPHIES

Atmakuri Venkata Pavani,she currently persuing final year B.Tech in Computer Science Engineering at Vijaya Institute Of Technology for Women which is affliated to JNTUK.

Davuluri Naina, she currently persuing final year B.Tech in Computer Science Engineering at Vijaya Institute Of Technology for Women which is affliated to JNTUK.

R.Nagendra Babu,He is an assistant professor in computer science and engineering Department in Vijaya Institute of Technology for Women,Vijayawada,

N.Swarna Jyothi, she is an assistant professor in computer science and engineering Department in Vijaya Institute of Technology for Women, Vijayawada,

S.Chinna Gopi, He is an assistant professor in computer science and engineering Department in Vijaya Institute of Technology for Women, Vijayawada,