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Swarm Intelligence Techniques focusing on PSO and ACO

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Abstract - Swarm intelligence (SI) is the collective behavior of decentralized, self-organized systems, natural or artificial. The concept is employed in work on (AI)artificial intelligence. SI systems consist typically of a population of simple agents or boids interacting locally with one another and with their environment. The inspiration often comes from nature, especially biological systems. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local, and to a certain degree random, interactions between such agents lead to the emergence of "intelligent" global behavior, unknown to the individual agents. Examples in natural systems of SI include ant colonies, bird flocking, animal herding, bacterial growth, fish schooling and microbial intelligence. The application of swarm principles to robots is called swarm robotics, while 'swarm intelligence' refers to the more general set of algorithms. This paper comprises a snapshot of particle swarm optimization and Ant colony optimization, including variations in the algorithm, current and ongoing research, applications.

Key words: swarm intelligence, Artificial Intelligence, particle swarm optimization, Ant colony optimization.

1. Introduction

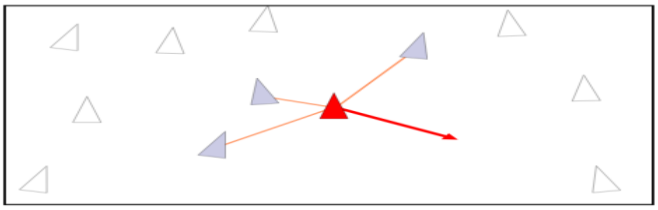
There are various techniques of swarm intelligence used by various researchers. Following are the few of them. In this paper we mainly discuss two techniques name P.S.O (Particle swarm Optimization) and A.C.O (Ant Colony optimization)

1. Particle swarm optimization
2. Ant colony optimization
3. Artificial bee colony algorithm.
4. Differential evolution.
5. The Bees algorithm.
6. Artificial immune systems.
7. Bat Algorithm.
8. Glowworm Swarm optimization.
9. Gravitational Search algorithm.

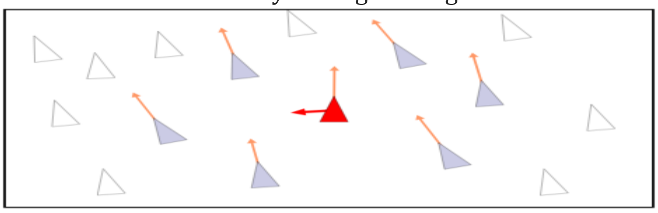
"Boids" model was proposed by Reynolds
Boids= Bird-oids(bird like)

There are 3 Simple Rules:

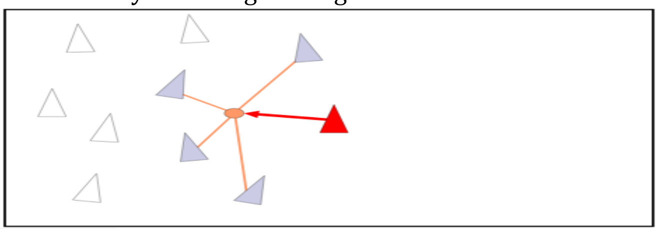
Rule 1: Avoid Collision with neighboring birds



Rule 2: Match the velocity of neighboring birds



Rule 3: Stay near neighboring birds



1.1 Particle swarm optimization

Particle Swarm Optimization (PSO) is a global optimization algorithm for dealing with problems in which a best solution can be represented as a point or surface in an n-dimensional space. Hypotheses are plotted in this space and seeded with an initial velocity, as well as a communication channel between the particles. Particles then move through the solution space, and are evaluated according to some fitness criterion after each time step. Over time, particles are accelerated towards those particles within their communication grouping which have better fitness values. The main advantage of such an approach over other global minimization strategies such as simulated annealing is that the large number of members that make up the particle swarm make the technique impressively resilient to the problem of local minima

PSO Algorithm

Step 1: Each particle (or agent) evaluates the function to maximize at each point it visits in spaces.
Step 2: Each agent remembers the best value of the function found so far by it (pbest) and its co-ordinates.
Step 3: Each agent know the globally best position that one member of the flock had found, and its value (gbest).

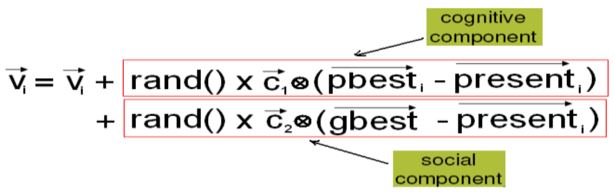
Algorithm –Phase 1 (1D)

Using the co-ordinates of pbest and gbest, each agent calculates its new velocity as:

vi = vi+ c1 x rand() x (pbestxi–presentxi) + c2 x rand() x (gbestx –presentxi)

where 0 < rand() <1
presentxi= presentxi+ (vix Δt)

Algorithm –Phase 2 (n-dimensions)



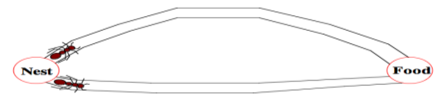
Note that the symbol ⊗ denotes a point-wise vector multiplication.

```
Randomly generate an initial population
repeat
        for i = 1 to population_size do
               if f(present_i) < f(pbest)
                   then pbest = present_i;
               gbest = best(pbest);
               for d =1 to dimensions do
                       velocity_update();
                       position_update();
               end
        end
until termination criterion is met.
```

1.2 Ant colony optimization

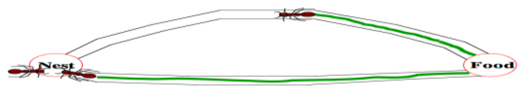
ACO, introduced by Dorigo in his doctoral dissertation, is a class of optimization algorithms modeled on the actions of an ant colony. This is basically inspired by foraging behavior of ants. Ants find shortest path to food source from nest. Ants deposit pheromone along traveled path which is used by other ants to follow the trail. This kind of indirect communication via the local environment is called stigmergy. ACO is a probabilistic technique useful in problems that deal with finding better paths through graphs. Artificial 'ants'—simulation agents—locate optimal solutions by moving through a parameter space representing all possible solutions. Natural ants lay down pheromones directing each other to resources while exploring their environment. The simulated 'ants' similarly record their positions and the quality of their solutions, so that in later simulation iterations more ants locate better solutions.

Foraging behavior of Ants:

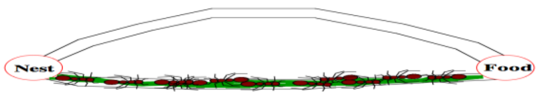


2 ants start with equal probability of going on either path.

The ant on shorter path has a shorter to-and-fro time from it's nest to the food.



The density of pheromone on the shorter path is higher because of 2 passes by the ant (as compared to 1 by the other).



After some time, the shorter path is almost exclusively used.

ACO algorithm 1:

Pheromone updated by all ants in the iteration.

$$\tau_{ij} \leftarrow (1-\rho)\cdot\tau_{ij} + \sum_{k=1}^{m}\Delta\tau_{ij}^{k}$$

$$\Delta\tau_{ij}^{k} = \begin{cases} Q/L_k & \text{if ant } k \text{ used edge } (i,j) \text{ in its tour,} \\ 0 & \text{otherwise,} \end{cases}$$

Ants select next vertex by a stochastic function which depends on both pheromone and problem-specific heuristic $n_{ij} = 1/d_{ij}$.

ACO algorithm 2: MAX-MIN Ant System (MMAS):

This variation improves over algo1. In this approach only best ant updates pheromone. Value of pheromone is bound.

$$\tau_{ij} \leftarrow \left[(1-\rho)\cdot\tau_{ij} + \Delta\tau_{ij}^{\text{best}}\right]_{\tau_{min}}^{\tau_{max}}$$

$$\Delta\tau_{ij}^{\text{best}} = \begin{cases} 1/L_{\text{best}} & \text{if } (i,j) \text{ belongs to the best tour,} \\ 0 & \text{otherwise.} \end{cases}$$

Lbest = length of tour of best ant. Bounds on pheromone are problem specific.

2. Ant-based routing:

The use of Swarm Intelligence in telecommunication networks has also been researched, in the form of ant-based routing. This was pioneered separately by Dorigo et al. and Hewlett Packard in the mid-1990s, with a number of variations since. Basically this uses a probabilistic routing table rewarding/reinforcing the route successfully traversed by each "ant" (a small control packet) which flood the network. Reinforcement of the route in the forwards, reverse direction and both simultaneously have been researched: backwards reinforcement requires a symmetric network and couples the two directions together; forwards reinforcement rewards a route before the outcome is known (but then you pay for the cinema before you know how good the film is). As the system behaves stochastically and is therefore lacking repeatability, there are large hurdles to commercial deployment. Mobile media and new technologies have the potential to change the threshold for collective action due to swarm intelligence (Rheingold: 2002, P175).The location of transmission infrastructure for wireless communication networks is an important engineering problem involving competing objectives. A minimal selection of locations (or sites) are required subject to providing adequate area coverage for users. A very different-ant inspired swarm intelligence algorithm, stochastic diffusion search (SDS), has been successfully used to provide a general model for this problem, related to circle packing and set covering. It has been shown that the SDS can be applied to identify suitable solutions even for large problem instances.

Airlines have also used ant-based routing in assigning aircraft arrivals to airport gates. At Southwest Airlines a software program uses swarm theory, or swarm intelligence—the idea that a colony of ants works better than one alone. Each pilot acts like an ant searching for the best airport gate. "The pilot learns from his experience what's the best for him, and it turns out that that's the best solution for the airline," Douglas A. Lawson explains. As a result, the "colony" of pilots always go to gates they can arrive at and depart from quickly. The program can even alert a pilot of plane back-ups before they happen. "We can anticipate that it's going to happen, so we'll have a gate available," Lawson says.

3. Crowd Simulation:

Artists are using swarm technology as a means of creating complex interactive systems or simulating crowds.

Stanley and Stella in: Breaking the Ice was the first movie to make use of swarm technology for rendering, realistically depicting the movements of groups of fish and birds using the Boids system. Tim Burton's Batman Returns also made use of swarm technology for showing the movements of a group of bats. The Lord of the Rings film trilogy made use of similar technology, known as Massive, during battle scenes. Swarm technology is particularly attractive because it is cheap, robust, and simple.

Airlines have used swarm theory to simulate passengers boarding a plane. Southwest Airlines researcher Douglas A. Lawson used an ant-based computer simulation employing only six interaction rules to evaluate boarding times using various boarding methods. (Miller, 2010, xii-xviii).

Applications

Swarm Intelligence-based techniques can be used in a number of applications. The U.S. military is investigating swarm techniques for controlling unmanned vehicles. The European Space Agency is thinking about an orbital swarm for self-assembly and interferometry. NASA is investigating the use of swarm technology for planetary mapping. A 1992 paper by M. Anthony Lewis and George A. Bekey discusses the possibility of using swarm intelligence to control nanobots within the body for the purpose of killing cancer tumors. Conversely al-Rifaie and Aber have used Stochastic Diffusion Search to help locate tumours. Swarm intelligence has also been applied for data mining.

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