Modifying Ant Colony Optimization by Introducing the Concept of Perception Radius

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Abstract— **The main motive of Ant Colony Optimization (ACO) is to find the shortest path from the ants' nest to the food source by sensing the amount of pheromone (a chemical secreted by ants which is used as the communication system) on the different paths available. In this paper, we propose a novel methodology which solves the problem of an ant facing an obstacle in its path from the nest to the food source, in which case the conventional ACO may fail. This work proposes a modified ant colony optimization by introducing the concept of perception radius, for enabling the ants to find the path to the food source even if there is any break in the pheromone trail. The Travelling Salesman Problem, as an example, is solved using the proposed modified ACO and the results obtained are compared with Dijkstra's algorithm. It is clearly demonstrated that our methodology not only works well when breaks or hurdles are encountered by ants but also provides efficient results.**

Key Words — **ACO, Modified Ant Colony Optimization, Perception Radius.**

I. INTRODUCTION

Swarm Intelligence, introduced by Gerardo Beni and Jing Wang in 1989, is a technique in which the collective behaviour of agents is considered [1]. These agents interact with other individuals and with their local environment. Ant Colony Optimization (ACO) [2] is one of the various concepts of Swarm Intelligence. ACO was first introduced by Marco Dorigo in 1992. Ants are socially organised insects and because of this organization, ant colonies are able to crack even the complex tasks which had not been accomplished by an individual ant. Initially, ants move randomly in search of the food from their nest and while doing so, they leave a chemical called pheromone along the path they trace. The pheromone laid along the path to the food source by the foragers is the main source which guides other ants to the food source. This whole phenomenon which includes trail-laying and trail-following behaviour of ants is the main source of inspiration in ACO [2]. ACO has attracted a huge number of researchers since the early nineties. Wei Gao proposed an immunized ant colony optimization, wherein the ant individuals are transformed by adaptive cauchi mutation and thickness selection [4]. Sun et al. proposed a K-means-ACO algorithm for solving the misclassification problem of K-Means and slow convergence of ACO [5]. Suruchi et al. classified mixed pixels in a remote sensing image by fusing ACO and Biogeography Based Optimization [6]. In this paper we attempt to modify the conventionally used ACO by integrating the concept of Perception Radius.

The rest of the paper is organized as: Section II describes the concept of Perception Radius which is introduced in modified ACO, Section III provides the proposed modified ant colony optimization, Section IV gives the experimental results and performance analysis and Section V concludes the paper

II. PERCEPTION RADIUS

Perception Radius (þ) is defined as the minimum distance to which the ants can sense the pheromone if a break or hurdle in the path from the nest to the food source or from the food source to the nest is encountered. In other way, it can be visualized as: an ant on which radar has been fixed and with the help of this radar, it can smell the pheromone to the next þ distance units from its current position. As a step further towards the definition of perception radius, consider the graph given in Fig. 1, which is a model used in Double Bridge Experiment (Deneuberg et al.) [3].

The graph has two nodes, out of which one depicts the nest (node 1) and the other depicts the food source (node 2). The nodes are connected by two arcs which represents the path traced by the ants. One way to reach is through longer path (arc 1-3-2), represented by l' and the other is via the shorter path (arc 1-2), represented by s'. The longer path l' is 'ŧ' times longer than s' i.e. the ratio l':s' is represented by ŧ. The time is taken as discrete and it is assumed that the ants move one unit distance per unit time adding one unit pheromone on the path they trace [3].

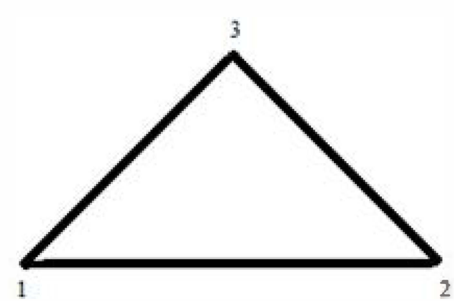

Fig. 1. Model used in Double Bridge Experiment

Now the question arises “What if there comes a hurdle, say a rock, just after node 1?” According to the conventional ACO, the ants will either return back or they will start wandering randomly in search of food due to absence of pheromone. But now when the ants are equipped with the radar, they can sense the pheromone to the next 'þ' distance from their current position and thus, can find their lost path as shown in fig. 2.

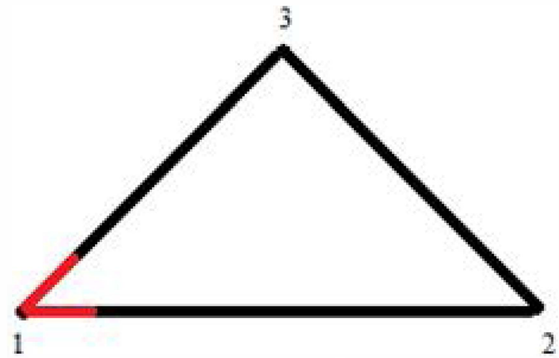

Fig. 2. Graph with break after node 1. Red line indicates the distance which lies within the perception radius of ant.

In the figure shown above, the red lines indicate the distance þ (perception radius) till where the ants can sense the pheromone. There can be three possibilities from here on:

A. If l' i.e. the path 1-3-2 and s' also comes within the perception radius of ant.

B. If l' comes within the perception radius and s' does not.

C. If s' comes within the perception radius of ant while l' does not.

A. l'=þ=s’

In this case, after the break, the distance between node 1 and the shorter path and the distance between node 1 and the longer path come within the perception radius of the ant. The ants would now follow the normal ACO algorithm i.e. they would now move towards either of the two paths probabilistically: $f_{is}(t)$ is the probability for an ant located at node 1 at time t to choose the shorter path, and $f_{il}(t)$ the probability to choose the longer path. These probabilities depend on the pheromone concentration on the arcs which the ants choose [3].

$$f_{is}(t) = \frac{[[\epsilon]_{is}(t)]^{\alpha}}{[\epsilon_{is}(t)]^{\alpha} + [[\epsilon]_{il}(t)]^{\alpha}} \qquad (1)$$

Pheromone update on the two branches is as follows:

$$f_{is}(t) = f_{is}(t-1) + f_{is}(t-1).n_i(t-1) + f_{js}(t-1).n_j(t-1) \qquad (2)$$

$$f_{il}(t) = f_{il}(t-1) + f_{il}(t-1).n_i(t-1) + f_{jl}(t-t).n_j(t-t) \qquad (3)$$

where, n_i is the number of ants on node i and n_j is the number of ants on node j at any time t.

B. l' < þ < s’

In this case, the ants will smell the pheromone on the longer branch since the longer branch comes within the perception radius of the ants whereas the shorter branch does not. Now, the ants will choose the longer path i.e. probability of choosing the long trail at any time t, will be one and that of choosing the shorter path will be zero.

$$f_{il}(t) = 1 \qquad (4)$$

Pheromone update on the two branches is performed as follows:

From equation 2,

$$f_{is}(t) = f_{is}(t-1) + n_j(t-1).f_{js}(t-1) \qquad (5)$$

(Since, the probability of choosing the short path is zero i.e., $f_{is}(t) = 0$).

$$f_{il}(t) = f_{il}(t-1) + n_i(t-1) + n_j(t-r).f_{jl}(t-r) \qquad (6)$$

C. s' < þ < l'

In this case, the shorter path will come within the perception radius of the ants and therefore, they will trace the shorter path. Thus, the probability of choosing the shorter path at any time t will become one whereas that of choosing the longer one will be zero.

$$f_{is}(t) = 1 \qquad (7)$$

Pheromone update on both the branches will be as follows:

$$f_{is}(t) = f_{is}(t-1) + f_{js}(t-1).n_j(t-1) + n_i(t-1) \qquad (8)$$

$$f_{il}(t) = f_{il}(t-1) + f_{jl}(t-t).n_j(t-1) \qquad (9)$$

III. PROPOSED METHODOLOGY

Ant Colony Optimization is an iterative algorithm [3] in which at each step i.e. at each node the ant has to select from all the paths available to reach the node which finally leads it to its destination or the food source. This selection is based on the amount of pheromone deposited on the path from any node 'i' to the next node 'j'. The path with more pheromone concentration which leads to a node which has not been visited yet is selected by the ants. When an ant faces a hurdle or break in the path, it tries to sense the pheromone till the 'þ' distance units from its current position. Whichever path lies in the perception radius of the ant, the ant chooses that path to reach the food source even if it is longer than the other available ones.

The modified ant colony optimization algorithm that is proposed in this paper is stated below:

- Initialize pheromone trail values.
- Initially, some ants are placed on the nest and they will trace the path to the food source while some are at the destination and they will trace their path back to the ants' nest.

While the termination condition (the ants from their nest reach the food source or vice versa) does not meet do

Ants construct the solution by moving from one node to the next till they reach their - destination provided that they do not visit an already visited node.

Pheromone will get updated after each time interval as below:

$$f_{is}(t) = f_{is}(t-1) + f_{is}(t-1).n_i(t-1) + f_{js}(t-1).n_j(t-1) \quad (10)$$

$$f_{il}(t) = f_{il}(t-1) + f_{il}(t-1).n_i(t-1) + f_{jl}(t-ŧ).n_j(t-ŧ) \quad (11)$$

Where n_i and n_j are number of ants at the node i and j respectively at time t.

- If condition
  Whenever an ant faces a hurdle or break in its path, it tries to smell the pheromone on all the paths lying within its perception radius. As and when it finds a suitable path (as described in Section II) it moves to that path.
- End while

We can describe it as:

i = 0;
node = 1;
do
{
i = i+1;
if (f == 0)
{
// check f at i = i+þ

if (l'<þ && s'>þ)
{

$$f_{is}(t) = f_{is}(t-1) + n_j(t-1).f_{js}(t-1)$$

$$f_{il}(t) = f_{il}(t-1) + n_i(t-1) + n_j(t-r).f_{jl}(t-r)$$

else if(l' = þ = s')
{

$$f_{is}(t) = f_{is}(t-1) + f_{is}(t-1).n_i(t-1) + f_{js}(t-1).n_j(t-1)$$

$$f_{il}(t) = f_{il}(t-1) + f_{il}(t-1).n_i(t-1) + f_{jl}(t-ŧ).n_j(t-ŧ);$$

}

else if (l'>þ && s'<þ)
{

$$f_{is}(t) = f_{is}(t-1) + f_{js}(t-1).n_j(t-1) + n_i(t-1);$$

$$f_{il}(t) = f_{il}(t-1) + f_{jl}(t-ŧ).n_j(t-1);$$

}// end if

else
{

$$f_{is}(t) = f_{is}(t-1) + f_{is}(t-1).n_i(t-1) + f_{js}(t-1).n_j(t-1)$$

$$f_{il}(t) = f_{il}(t-1) + f_{il}(t-1).n_i(t-1) + f_{jl}(t-ŧ).n_j(t-ŧ);$$

}

}
while (node = = n);

where,

- n is the last node in the path or the destination node.
- l' is the longer path from the source node to the destination node.
- s' is the shorter node connecting the source node and the destination node.
- f denotes the pheromone concentration.
- i denotes the distance.

In this work, the introduction to the concept of perception radius will make the ants capable of finding the path from the nest to the food source or vice versa even when there is no pheromone concentration due to breakage in the path. In the next section, we will try to prove the proposed methodology with the help of a Travelling Salesman Problem (TSP).

IV. EXPERIMENTAL RESULTS AND PERFORMANCE ANALYSIS

In this section, we aim at solving a Travelling Salesman Problem by using the proposed methodology. The TSP was proposed by Hassler Whitney in 1934 [7]. This problem aims at finding the shortest possible path from the source to the destination with the condition that each node should be visited only once [8].

In this work, we will only consider only that TSP in which all the nodes are on the plane and the graph is a connected one as given in fig. 3. Here node 'a' represents the nest of ants and node 'd' represents

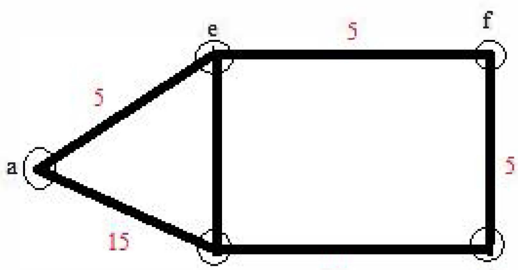

Fig. 3. Graph

the food source. The path from node 'a' to node 'd' via node 'b' is the shorter path while the other via node 'e' and node 'f' is the longer one.

PROBLEM STATEMENT: Suppose there is a hurdle (or a break in the path) from node 'b' to node 'c'. In this section, we solve the problem in which an ant finds the shortest path after coming across a break in its path by using the proposed methodology and then comparing the results by solving the same problem by some other method (Dijkstras algorithm). The new graph will look like as given in fig. 5. In the figure given below, the

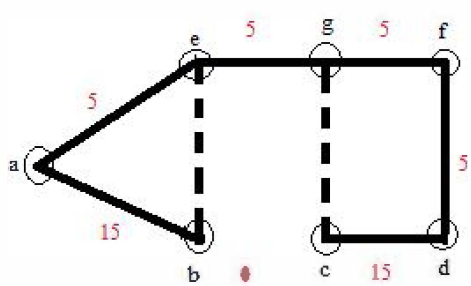

Fig. 4. Modified Graph

new pheromone values (numeric values in red coloured ink) at time t, are provided, post a break in the path from node 'b' to node 'c' and the dashed lines represent the path that the ants could trace due to breakage. Under the following assumptions, the given problem is solved:

- The ants move towards the path with higher pheromone concentration.
- Evaporation of pheromone is considered to be negligible.
- There was a break in the path when the absolute case occurred i.e. when the probability of choosing the short path became one.
- The ants move from one node to the next in one time unit.

The vertical distance i.e. edge 'be' or edge 'cg' is considered shorter as compared to the horizontal edges (edge 'bc' or edge 'gf'). Hence the vertical edges lie within the perception radius whereas the horizontal ones do not.

SOLUTION: At time t, suppose 20 ants are at node 'a' and 20 ants are at node 'd'. f_{ij} denotes the pheromone concentration on the path joining node 'i' and node 'j' whereas f_{ji} denotes pheromone deposited by the ants moving in backward direction i.e. from node 'i' to node 'j'.

- **At time t + 1**

The ants which were at node 'a' at time 't' will reach node 'b' and the ants which were at node 'd' will reach node 'c' at time 't + 1'.

$f_{ab} = 35$

$f_{dc} = 15 + 20 = 35$

- **At time t + 2**

The ants at node 'b' will face the hindrance since there is no pheromone due to the breakage in the path from node 'b' to node 'c'. They will try to smell the pheromone in the nearby area lying within their perception radius. The node 'e', supposedly, being closer will lie within its perception radius. The ants will then move to node 'e'. The distance between node 'b' and node 'c' is more than the perception radius and therefore, the ants at node 'c' will smell the pheromone at node 'g' and will move towards node 'g'.

$f_{be} = 20$

$f_{cg} = 20$

- **At time t + 3**

Now the ants at node 'e' can move either towards node 'a' or node 'g' since both the paths have equal concentration of pheromone. But, moving towards node 'a' will lead to a vertex which had already been visited. Therefore, the ants at node 'e' will reach node 'g' and those at node 'g' will reach node 'e'.

$f_{eg} = 20$

$f_{ge} = 20$

That is' after time t + 3, the total pheromone concentration on the branch eg will be:

$f_{eg} = 20 + 20 + 5 = 45$

- **At time t + 4**

The ants at node 'e' will reach node 'b' since pheromone concentration on the branch ea is less as compared to that on branch eb and those at node 'g' will reach node 'c'.

$f_{eb} = 20 + 20 = 40$
$f_{gc} = 20 + 20 = 40$

- **At time t + 5**

The ants at node 'c' will reach the food source ants at node 'b' will reach their nest.

$f_{cd} = 35 + 20 = 55$
$f_{ba} = 35 + 20 = 55$

The new graph after time t + 5 will be as shown in fig. 5.

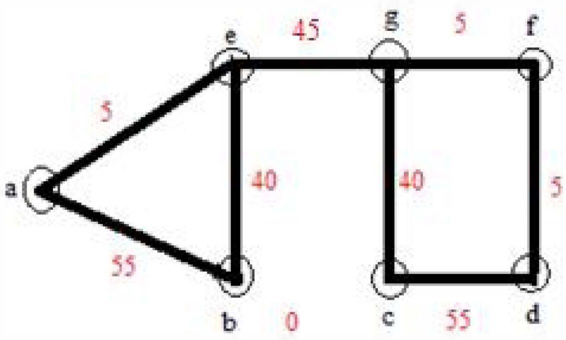

fig. 5. New graph after time t + 5

Therefore, new ants at time t + 6 time will follow the path
a → b → e → g → c → d

A. Verifying the solution of the graph using Dijkstra's algorithm.

Assumptions:

- Unlike in normal Dijkstra's algorithm [9] in which the path with minimum cost is selected, we will consider the path with maximum cost (cost here denotes the pheromone concentration) because ants move towards the path with more pheromone concentration. We will be calculating min (v_j, v_i + w) where v_j is the next node, v_i is the current node and w is the pheromone on the path connecting node 'i' and node 'j'.

- The initial cost is taken as minimum say, zero instead of infinity (maximum), since ants prefer the path with more pheromone concentration.

- Node 'a' is considered to be stable or the source vertex [10] and its value is taken to be infinity.

- While finding out the most stable vertex, the node with maximum value is selected.

- If at a moment, more than one node has the same value and that value is the maximum then any one vertex out of these vertices can be chosen as stable vertex arbitrarily.

Following is the solution by Dijkstra's algorithm:

a	b	c	d	e	f	g
∞	0	0	0	0	0	0
∞	0	0	0	0	0	0
∞	0	0	0	40	0	0
∞	0	40	40	40	40	85
∞	0	125	40	40	90	85

Using this, if the ant gets stuck at node 'b' after coming from node 'a', the shortest path traced by it comes out to be:

a→ b→ e→ g→ c→ d

which is same as the solution calculated by modified ACO that has been proposed in this paper. The results obtained clearly vindicate our algorithm. Thus the proposed methodology not only overcomes the drawback of the conventional ACO in the cases when hurdles or breaks are encountered by ants in their paths but also provides efficient results.

V. CONCLUSION

In the normal situations, if the ant faces a hurdle or a break in its path from the nest to the food source, it will assume that there is no food because of zero concentration of pheromone. Since the ants were not equipped with perception radius, they would either return back to their nest or would simply wander randomly in search of food. Therefore, the conventional ACO algorithms fail when obstacles or breaks are encountered by ants in their search of food. The methodology that is proposed in this work equips ants with the ability to find food in situations where normal ACO would fail by providing them with a perception radius. The results obtained indicate that our algorithm is very effective and clearly overcomes the drawback of normal ACO.

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