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Application of Ant Colony Optimization Algorithm for PCB Drilling Tool Path Minimization

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Abstract*: Ant colonies, and more commonly social insect societies, are scattered structures that, in spite of the simplicity of their individuals, present a highly well thought-out social organization. Because of this enterprise, ant colonies can accomplish complex duties that in some instances a ways exceed the individual capacity of a single ant. This paper focus on ant colony and behaviour of ant when it searches for food. Most of the conversation among individuals and between individuals and environment in an ant colony is based on use of chemical produced by Ants. These chemicals are called "pheromones". "Trail Pheromone" is a specific type of pheromone that some ant species use for marking paths on the ground. In this paper the trail pheromone behaviour and its mathematical model is used for finding minimum length tool path for a PCB drilling process. The problem is also similar to travelling salesman problem(TSP) and solution method is similar to the solution of TSP with the only difference in terms of distance values and the route method.
***Keywords*: Ant colony optimization, Travelling salesman problem, PCB drilling tool path optimization.**

I. INTRODUCTION

This document is a template. For questions on paper guidelines, he PCB drilling process is often performed by CNC machines where a 3 axis motion of tool will do the process of drilling holes at given co-ordinates on PCB. To save power and cycle time in PCB drilling, a CNC tool should traverse through the path such that the total distance travelled is minimum. So the drilling sequence is required to be optimized for minimum total distance travelled. Normally CAD CAM software provide facility to output a drill chart which shows the co –ordinates of the points on PCB plane where holes has to be drilled. So CNC machine operates on those co-ordinates and the drilling process is done automatically.

The problem is equivalent to Symmetric TSP where the tool has to traverse through the points to be drilled in such a way that total distance travelled is minimized and all the holes are visited once and only once.

II. PROBLEM FORMULATION AND CONSTRAINTS

An Mathematically problem can be expressed as,

$$Min(C_{total}) = \sum_{i=1}^{n}\sum_{j=1}^{n}\sqrt{((xi - xj)^2 + (yi - yj)^2)} \times P_{ij}$$

Where Pij = 1 if the tool has moved from point i to point j and Pij = 0 otherwise.

Subject to $\sum_{i=1}^{n} xij = 1, \ \sum_{j=1}^{n} xij = 1$

This is quite similar to the basic definition of symmetric TSP (STSP) [1].

A solution of this problem, 'K', forms a toolpath by visiting each co-ordinate at least once and completing drilling process there. It can be represented as a set of 'n' ordered pairs of x-y coordinates as

K = {(i1,i2),(i2,i3), …….. (in-1,in), (in,i1)}

Here each element (ij) refers to a node of the tour.

The method to obtain optimal solution for this problem is very difficult because there are so many feasible solutions. The time taken to obtain solution is not predictable

III.ANTS FOR AGEING BEHAVIOUR AND OPTIMIZATION

The visual insightful power of many ant groups is only incompletely developed and there are ant species that are totally sightless. Most of the conversation among individuals and between individuals and environment is based on use of chemical produced by Ants. These chemicals are called "pheromones". This is different from human and other higher species whose most important senses are visual and acoustics [3].

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"Trail Pheromone" is mainly significant for social life of some ant species. It is a specific type of pheromone that some ant group use for marking paths on the ground, for example, paths from food sources to the shell.

By sensing pheromone trails foragers can follow the path to food discovered by other ants. This group trail-laying and trail-following behaviour whereby an ant is manipulated by a chemical trace left by other ants is the stimulating source of ACO [3].

The foraging performance of many ant species is based on indirect conversation intervened by pheromones. While walking from food sources to the shell and vice versa, ants deposit pheromones on the ground, forming in this way a pheromone trail. Ants can smell the pheromone and they tend to opt, probabilistically, paths marked by strong pheromone absorption.

IV. ARTIFICIAL ANTS AND ANT SYSTEM

In PCB drilling process using CNC machine or ROBOT arm, the drilling tool starts from its initial position, routes through the PCB plane according to drill table provided to it, and drills the holes at the given co-ordinates on the PCB. To minimize the travel length, ant colony can be used in following way.

First the population or the number of ants required for solution formation is decided according to the number of holes on the PCB. This is nearly the double of total holes to be drilled, often with the minimum value of 25 ants.

After initializing the population the second parameter to be initialized is the initial pheromone level on path connecting each of the nodes with all other nodes. So if total 'n' numbers of nodes are given the initial pheromone assigned to all will be a matrix of *nxn* size, or total *nxn* values will be assigned. The initial pheromone level is calculated by following equation.

$$Tij(0) = T0 = \frac{1}{N \times C_{random}} \qquad (1)$$

Where N is number of holes, C_{random} is the cost or total distance of the sequence generated randomly (sometimes the nearest neighbor method).

After initialization process, each ant is kept to its first selected hole randomly. Then any ant positioned at hole 'i' the next hole to be visited by that particular ant at any iteration 't' will be selected based on following transition rule [2].

$$S = \begin{cases} argmax_{u \in N_h^i(t)} \{t_{ij}(t)\eta_{ij}(t)\}, r < r0 \\ S \qquad , r \geq r0 \end{cases}$$

Where r_0 and r are the numbers that control the ratio of exploration (capability of ant searching path by itself) and exploitation (foragers behavior).

It can be seen here that the transition depends on the pheromone level associated with any branch of path, and also the heuristic value (n_{ij}) which depends on the distance between the two holes.

As $n_{ij} = 1/c_{ij}$, c_{ij} is the distance between hole i and hole j.

Here, a taboo list is employed to remember the previously visited holes and to prevent an ant from choosing the previously visited hole.

In above equation (2) the N_h^i is the set of valid holes and the S is the randomly selected hole according to the probability p_{ij} given by [2].

$$p_{ij} = \frac{T_{ij}\eta_{ij}}{\sum T_{ij}\eta_{ij}} \qquad (3)$$

Once the ant chooses the next destination, the pheromone level at that branch is updated by following formula. This is called local pheromone update [2].

$T_{ij}(t+1) = (1-\rho)T_{ij}(t) + \rho_1 T_0$ (4)

Where

$\Delta T = 1/C_{bestant}$ and $C_{bestant}$ is the cost of best solution given by best ant.

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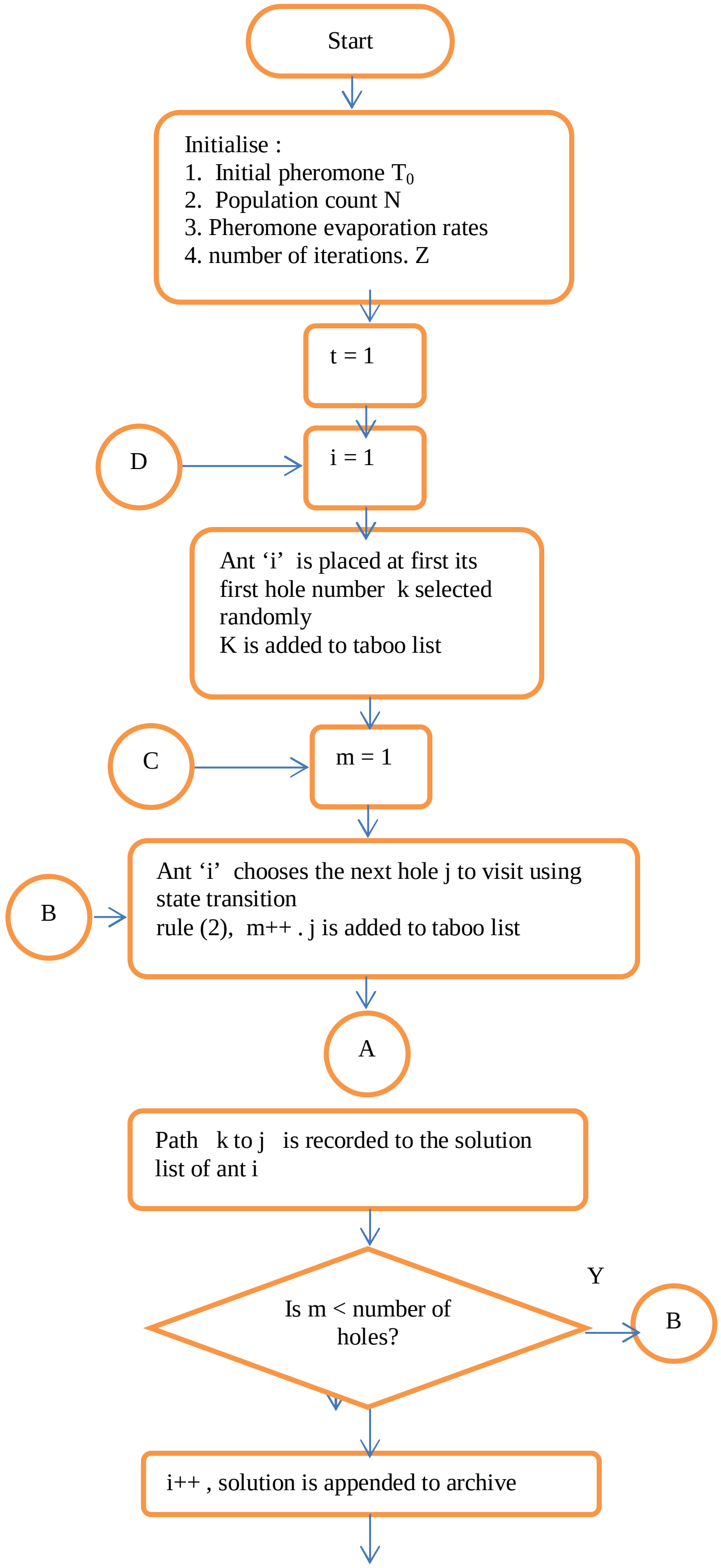
V. FLOWCHART OF ACO FOR PCB DRILLING



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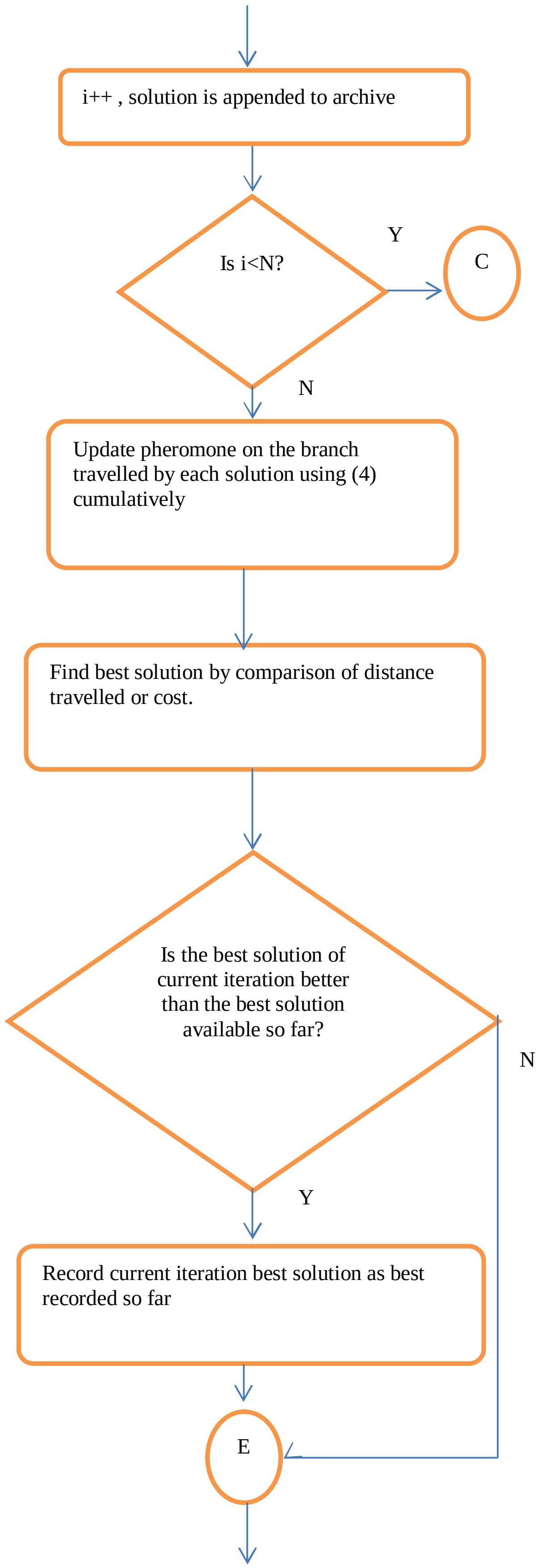

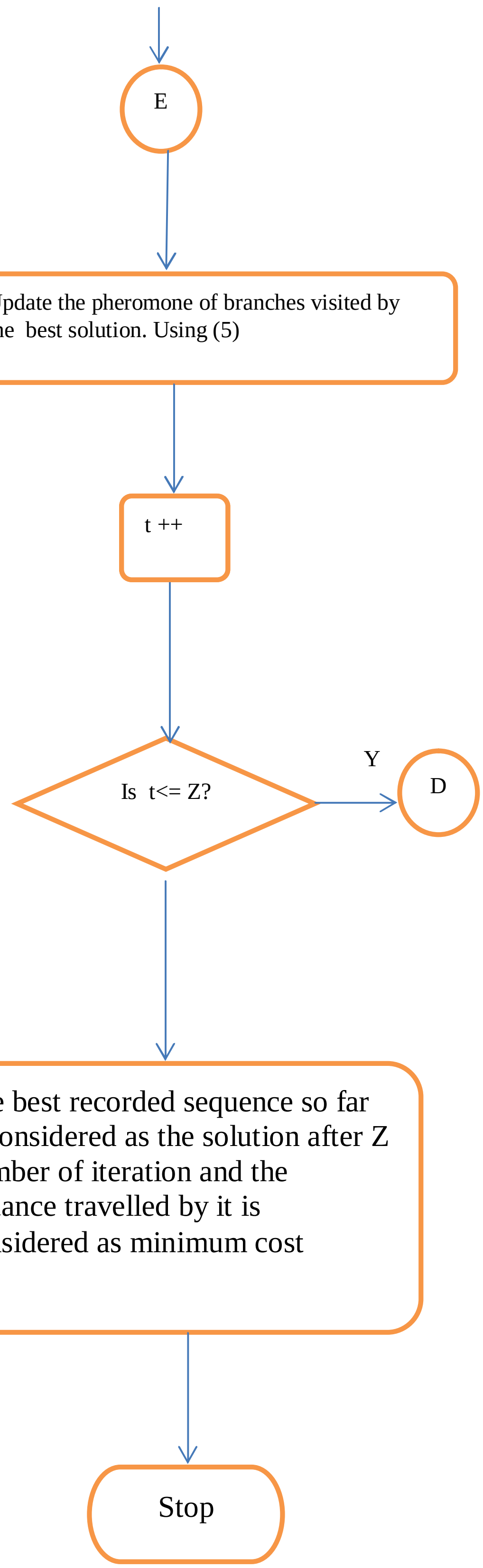
E
Update the pheromone of branches visited by the best solution. Using (5)
t ++
Is t<= Z?
Y
D
The best recorded sequence so far is considered as the solution after Z number of iteration and the distance travelled by it is considered as minimum cost
Stop

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VI. IMPLEMENTATION AND RESULT

The code of above algorithm is developed in MATLAB environment and tested for solution of the drilling toolpath solution of the PCB given in the figure below.

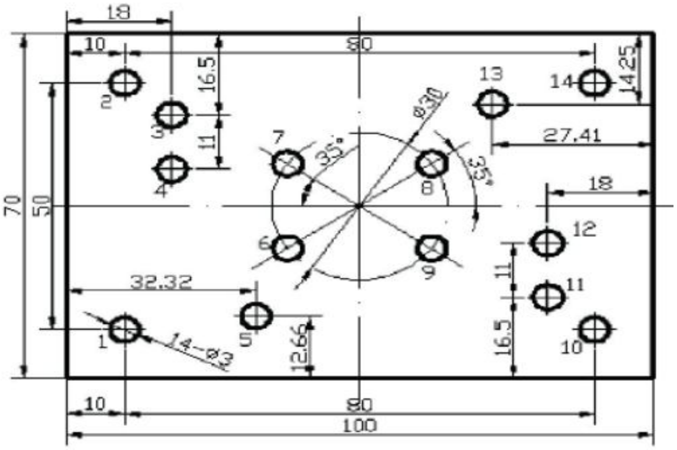

Fig. 1 Case study of a PCB containing 14 holes

Recommended Here the MATLAB function accepts the 2xZ matrix of drill coordinates and the algorithm is run for 100 iterations. After all iterations are over, the best solution along with the cost or distance for best solution are returned to the command window and the tool path for best solution is simulated in figure as a plot.

The matrix containing drill chart passed for the above PCB is a = [(10,10) (10,60) (18,53.5) (32.32,12.66) (43.45,30.41) (43.45,39.59) (56.55,39.59) (56.55,30.41) (90,10) (82,16.5) (82,27.5) (72.59,55.7) (90,60)]

The results obtained by running MATLAB code are as per given in the diagram below.

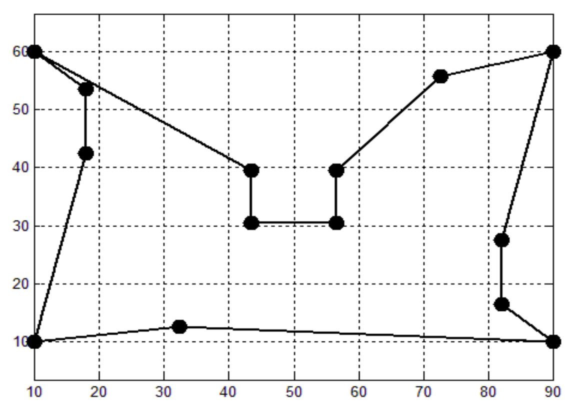

Fig. 2 MATLAB Results

The MATLAB command window snapshots are as given below.

```
>> [b c] = toolpath_pcb(a)

b =

  Columns 1 through 8

   18.0000   18.0000   10.0000   43.4500   43.4500   56.5500   56.5500   72.5900
   42.5000   53.5000   60.0000   39.5900   30.4100   30.4100   39.5900   55.7500

  Columns 9 through 15

   90.0000   82.0000   82.0000   90.0000   32.3200   10.0000   18.0000
   60.0000   27.5000   16.5000   10.0000   12.6600   10.0000   42.5000


c =

  301.1104

>> |
```

Where *b* shows the output sequence calculated for given matrix of drill chart and *c* is the total cost of circular path i.e. starting from first node to last and then back to first node.

VII. CONCLUSION

By this study it can be concluded that ACO is a powerful genetic algorithm for optimization of path finding or sequencing for minimum cost. This can also be applied to other TSPs as well. The technique is far better than the taboo search algorithm in which all possible paths were found and the cost was compared. If we assume 100 nodes which is a normal case, the number of iterations required in that would be factorial of 100. This algorithm can be modified for other CNC applications of tool path optimization where milling or turning process is required.

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