Robot swarm foraging using ant colony optimization

A report submitted in fulfilment of the requirements for the award of summer internship of

Bachelor of Technology

Submitted by:

Rajdeep Kalita (18-1-3-032)

Abhijit Shil (18-1-3-039)

Arindam Choudhury (18-1-3-041)

Vineet Kumar Choudhary (18-1-3-048)

Suvrajeet Kumar(18-1-3-028)

Under the supervision of:

Dr.NabanitaAdhikary

Assistant Professor

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY SILCHAR

ASSAM(788010)

ACKNOWLEDGEMENT

We would like to express our heartfelt gratitude to our madam, **Dr.NabanitaAdhikary, Assistant Professor, Department of Electrical Engineering**. She helped a great deal in us choosing this topic for our summer internship. We consider ourselves lucky to have gotten such a guide who is so cooperative and sincere. We will be forever grateful for her key suggestions, keen interest and precious time throughout the internship period.

Apart from her, we would also like to thank all the faculties of the electrical department in encouraging us to come up with new ideas and help us implement them efficiently and thanks to all the other people who helped us in developing this report in any way or the other.

.

Rajdeep Kalita (18-1-3-032)

Abhijit Shil (18-1-3-039)

Arindam Choudhury (18-1-3-041)

Vineet Kumar Choudhary (18-1-3-048)

Suvrajeet Kumar(18-1-3-028)

ABSTRACT

This Paper presents Robot Swarm foraging using ant colony optimization technique.Inthis paper we have discussed the best path for an ant swarm to find their food. The purpose of this report is to design an appropriate route to connect the the base station (where ant swarm are present) and aim(where the food is present) of the environment with obstacles. Path planning problem, is a challenging topic in robotics. Indeed, a significant amount of research has been devoted to this problem in recent years. The ant colony optimization algorithm is another approach to solve this problem.Each ant drops a quantity of artificial pheromone on every point that the ant passes through. This pheromone simply changes the probability that the next ant becomes attracted to a particular grid point.The techniques described in the paper adapt a global attraction term which guides ants to head toward the destination point.

Keywords— Path planning; Ant colony algorithm; collision avoidance.

CERTIFICATE

This is to certify that the research work entitled "**ROBOT SWARM FORAGING USING ANT COLONY OPTIMIZATION**" is a bonafied work carried out by Rajdeep Kalita(18-1-3-032), Abhijit Shil(18-1-3-039), Arindam Choudhury (18-1-3-041) Vineet Kumar Choudhary (18-1-3-048) and Suvrajeet Kumar(18-1-3-028) for the award of Summer internship. It is certified that the project report of their own work carried out during the period from 17 May 2021to 28 June 2021 (6th semester) under my supervision and this report has not been submitted elsewhere for anydegree/diploma.

Date:01-07-2021

………………………

Dr.NabanitaAdhikary
AssistantProfessor
Department ofElectricalEngineering
National Institute of Technology,Silchar
Assam-788010

TABLE OF CONTENTS

Contents

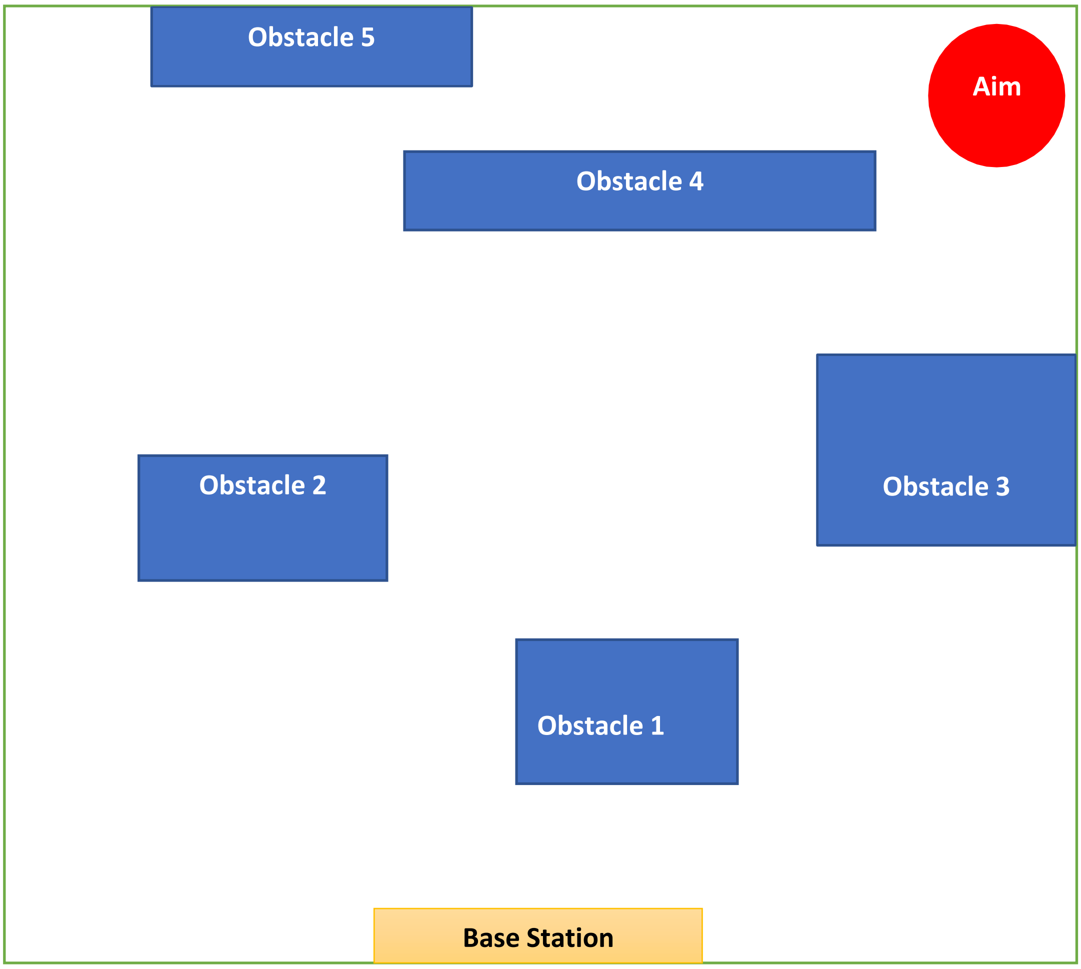
OBJECTIVE:

1. Find the model of a wheeled mobile robot and write a MATLAB code to simulate the robot motion.

2. Read the following paper and write a Matlab code or design Simulink model for Section IV: M. Dorigo, V. Maniezzo and A. Colorni, "Ant system: optimization by a colony of cooperating agents," in IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), vol. 26, no. 1, pp. 29-41, Feb. 1996, doi: 10.1109/3477.484436. This paper introduces the ant colony optimization technique.

3. Use ant colony optimization on a swarm of wheeled mobile robots as designed in 1 for performing the following task:

   Select an arena similar to as shown in Fig. 1. The swarm will start at the base station (starting point) (Fig. 1) and forage for the red aim (ending point) in the area with the obstacles.



INTRODUCTION:

In this paper we define a new general-purpose heuristic algorithm which can be used to solve different combinatorial optimization problems.In this algorithm where the “ants” follow the path of another ant to reach the goal point.Path planning, which is one of the hot topics in motion control research, requires the control object to determine the path,avoid obstacles and achieve the goal autonomously.In the approach discussed in this paper we distribute the search activities over so-called "ants," that is, agents with very simple basic capabilities which, to some extent, mimic the behavior of real ants. In fact, research on the behavior of real ants has greatly inspired our work .One of the problems studied by ethologists was to understand how almost blind animals like ants could manage to establish shortest route paths from their colony to feeding sources and back. It was found that the medium used to communicate information among individuals regarding paths, and used to decide where to go, consists of pheromone trails. A moving ant lays some pheromone (in varying quantities) on the ground, thus marking the path by a trail of this substance. While an isolated ant moves essentially at random, an ant encountering a previously laid trail can detect it and decide with high probability to follow it, thus reinforcing the trail with its own pheromone. The collective behavior that emerges is a form of autocatalytic behavior1 where the more the ants following a trail, the more attractive that trail becomes for being followed. The process is thus characterized by a positive feedback loop, where the probability with which an ant chooses a path increases with the number of ants that previously chose the same path.

Consider for example the experimental setting shown in Fig. 1. There is a path along which ants are walking (for example from food source A to the nest E, and vice versa, see Fig. 1a). Suddenly an obstacle appears and the path is cut off. So at position B the ants walking from A to E (or at position D those walking in the opposite direction) have to decide whether to turn right or left (Fig. 1b). The choice is influenced by the intensity of the pheromone trails left by preceding ants. A higher level of pheromone on the right path gives an ant a stronger stimulus and thus a higher probability to turn right. The first ant reaching point B (or D) has the sameprobability to turn right or left (as there was no previous pheromone on the two alternative paths). Because path BCD is shorter than BHD, the first ant following it will reach D before the first ant following path BHD (Fig. 1c). The result is that an ant returning from E to D will find a stronger trail on path DCB, caused by the half of all the ants that by chance decided to approach the obstacle via DCBA and by the already arrived ones coming via BCD: they will therefore prefer (in probability) path DCB to path DHB. As a consequence, the number of ants following path BCD per unit of time will be higher than the number of ants following BHD. This causes the quantity of pheromone on the shorter path to grow faster than on the longer one, and therefore the probability with which any single ant chooses the path to follow is quickly biased towards the shorter one. The final result is that very quickly all ants will choose the shorter path.

The algorithms that we are going to define in the next sections are models derived from the study of real ant colonies. Therefore we call our system Ant System (AS) and the algorithms we introduce ant algorithms. As we are not interested in simulation of ant colonies, but in the use of artificial ant colonies as an optimization tool, our system will have some major differences with a real (natural) one:

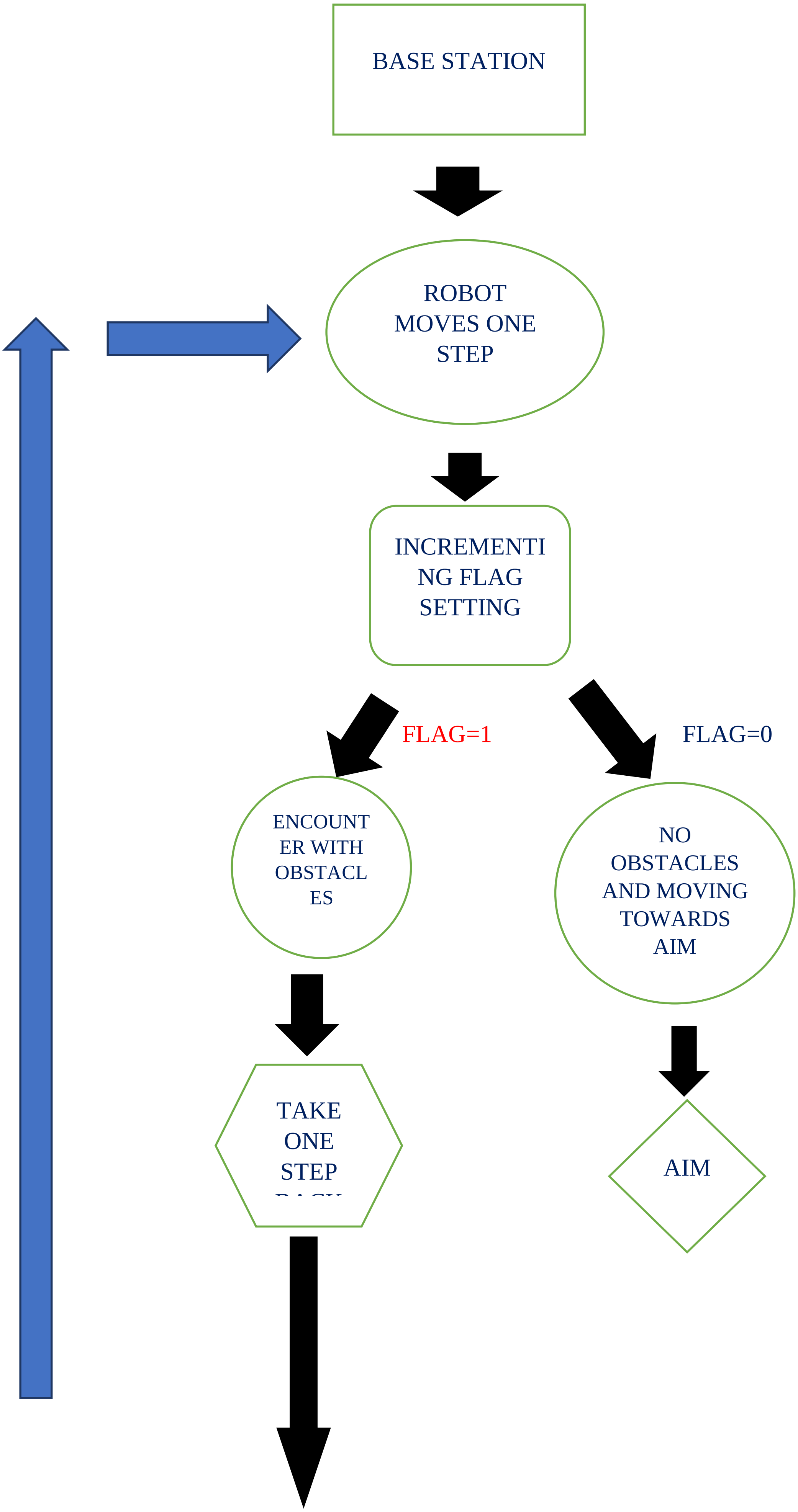
- artificial ants will have some memory,
- they will not be completely blind,
- they will live in an environment where time is discrete

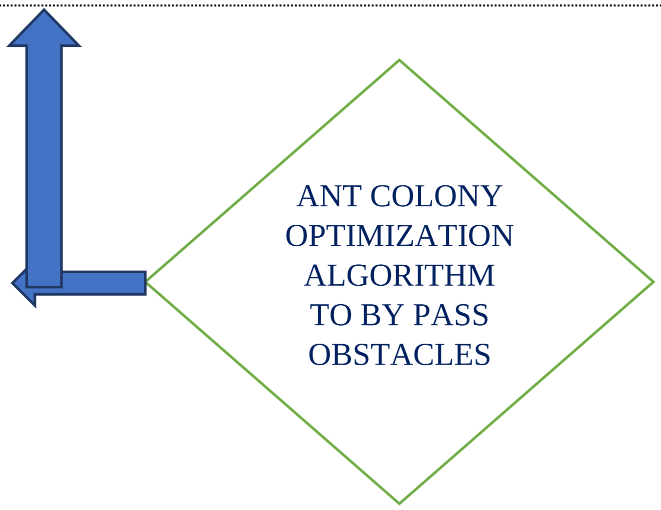
REVIEW OF LITERATURE

Yogita Gigras, Kusum Gupta [1] proposed algorithm for collision avoidance using backtracking and used the ant colony algorithm for finding the optimum shortest path to reach to the destination. Buniyamin N., Sariff N., Wan Ngah W.A.J., Mohamad Z.[2] worked together to solve the Robot Path Planning(RPP) problem. They proposed the accurate representation of heuristic and visibility equations of state transition rules. The proposed algorithm was applied within a global static map having feasible free space nodes. Michael Brand, Michael Masuda, Nicole Wehner, Xiao-Hua Yu [3] investigated the application of ACO to robot path planning in a dynamic environment. They compared two different pheromone re-initialization schemes and describe the best of them based on the simulation result. O. Hachour[4] proposed algorithm for path planning of autonomous mobile robot in an unknown environment. The robot travels within the environment sensing and avoiding obstacles that come across its way to the target station. Daniel Angus [5] modified the existing Ant System meta heuristic by including three parameters: cost, visibility and pheromone. Based on this a new algorithm for the Shortest Path Ant Colony Optimization(SPACO) was developed. The most important parameter included in this algorithm to solve shortest path problem is visibility. M.Dorigo, C. Blum [6] in Ant Colony Optimization theory: A Survey discussed the theoretical results of Ant Colony Optimization algorithms. They analyzed convergence results, connection between ACO algorithm and random gradient ascent within the model based search. Shahram Saeedi and IrajMahdavi[7] formulated a mathematical model to obtain the shortest path using Ant Colony Optimization. The model required calculation of shortest path between sources to target minimizing cost in the absence of any obstacle. Vinay Rishiwal et al. [8] proposed application of Ant Colony Optimization algorithm to find optimal paths in terrain maps. The algorithm uses penalty maps of the terrain maps as an input. The Terrain features such as land, forest etc are identified with different colors. Transition probability maintains a balance between pheromone intensity and heuristic information. Yee Zi Cong et al. [9] solved the mobile robot path planning problem using ACO algorithm. Each map consisted of static obstacles in different orientations. Each map was represented in a grid form with equal number of rows and columns. Song-Hiang Chia et al. [10] used Any Colony Optimization algorithm to solve the mobile robot path planning problem in such a way that the artificial ant reaches the target point from source point avoiding obstacles. The problem was modeled in a grid platform.

ALGORITHM FOR ROBOT PATH PLANNING

---1st flow chart-------------------------------------


BASE STATION
ROBOT MOVES ONE STEP
INCREMENTING FLAG SETTING
FLAG=1
FLAG=0
ENCOUNTER WITH OBSTACLES
NO OBSTACLES AND MOVING TOWARDS AIM
TAKE ONE STEP
AIM



The algorithm described below tries to avoid the collision and also suggest the steps to be followed during the occurrence of the obstacles.

1) Source Robot start walking from a fixed source point (Xs ,Ys) .

2) Robot Moves one step The value of (Xs ,Ys) is changed to (Xsnew,Ysnew) when the robot moves one step ahead by using the below equation:-

Xsnew=Xprev+step*cosΘ;

Ysnew=Yprev+step*sinΘ;

Where Xprev,Yprev denotes where the robot is currently situated. Robot's next position is determined by adding the product of step size and the cos(ɵ) and sin(ɵ).Where ɵ is dynamic angle and it can be calculated by:-

$\Theta = \tan^{-1}\frac{\mathrm{Xprev}}{\mathrm{Yprev}}$

3) Flag Setting

Robot see the value of the flag, if its value is zero it means there is no obstacle and robot can take a one step ahead to the destination point.

4) Encounter with obstacle

Whenever the robot encounter with obstacle, it has to stop moving. In our proposed work, 5 obstacle are generated which is of rectangular shape. Number of obstacles is fixed which a constraint in our work is.

5) Take one step back

Whenever the robot encounter with obstacle, robot stop moving and take three step back by using the following equation:

Xsnew=Xprev-step*cosΘ;

Ysnew=Xprev-step*sinΘ;

$\Theta = \tan^{-1}\frac{\mathrm{Xprev}}{\mathrm{Yprev}}$

6) Destination

Finally robot has to reach at the point (XT,YT), which is fixed. Robot has to bypass the obstacle and by following optimal path has to reach to target point.

7) Apply the ACO algorithm to bypass the obstacle ACO is used to find out the optimal one i.e. locally or globally optimal. This algorithm is implemented in two steps.

a) In first step, the edge is selected on the basis of probability formula. Assume that ant k is located at node i, uses the pheromone deposited on the edge (i,j) to compute the probability of choosing next nodeij

Pij = {$\frac{t_{ij}\alpha}{\sum j \in N_{i(k)} t_{ij}\alpha}$ if j ∈ Ni(k)

{ 0 otherwise

Where α denotes the degree of importance of pheromone trail and Ni(k) indicates the set of neighbor of ant k when located at node i except the last node visited by ant k, which helps to prevent the ant k for returning to the same node.

b) In second step, once all the ants complete their tour, then global optimization of the pheromone trail takes place.

tij = (1-p).p + $\sum_{k=1}^{N} dt_{ij}^{(k)}$

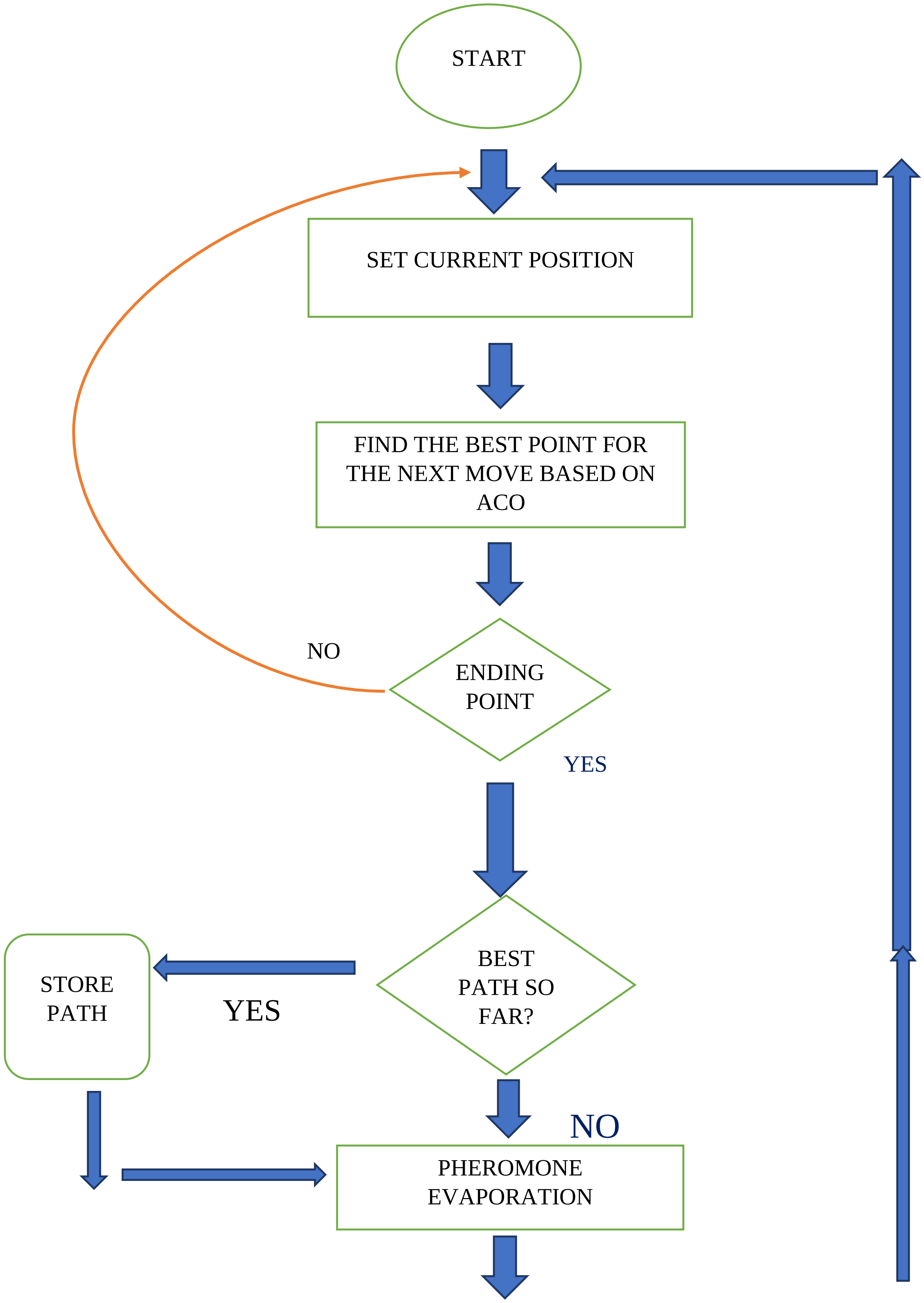
Where ρ Є (0,1) is the evaporation rate and τ ij(k) and is the amount of pheromone deposited on the edge (i,j) selected by the best ant k. The aim of pheromone updating is to increase the pheromone value associated with optimal path. The pheromone deposited on arc (i, j) by the best ant k is t ij(k) . Where, $\Delta t_{ij}(k) = \frac{Q}{L_k}$

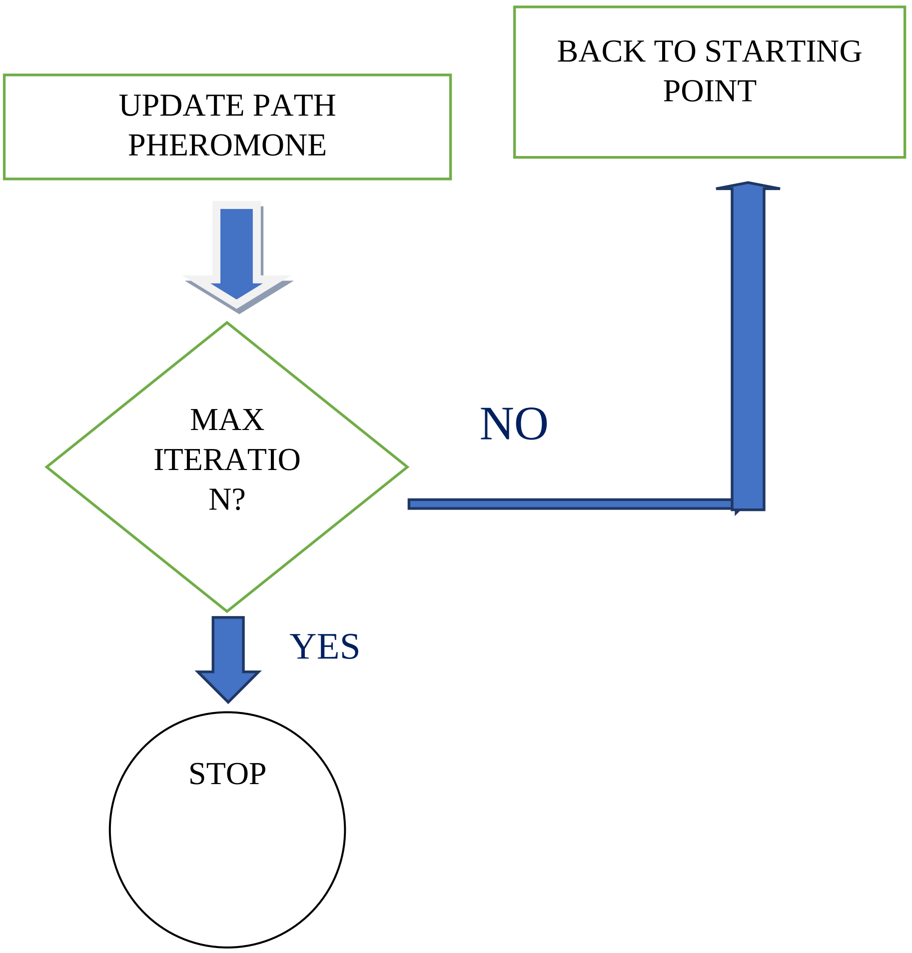
Here Q is a constant and Lk is the length of the path traversed by the best ant k. This equation is also implemented as:-

$\Delta t_{ij}(k)$ = {$\frac{T_{best}}{f_{worst}}$ if (i , j) ∈ global best tour

{0 otherwise

COMPUTATIONAL FLOW CHART OF ACO:





RESULTS AND DISCUSSION:

Here the red circles are marked as source station and destination.The lower circle is the source whereas the upper right is the destination circle.At the beginning the two robots move out from the source station and encounters and obstacle hence,move back and waits for decision making

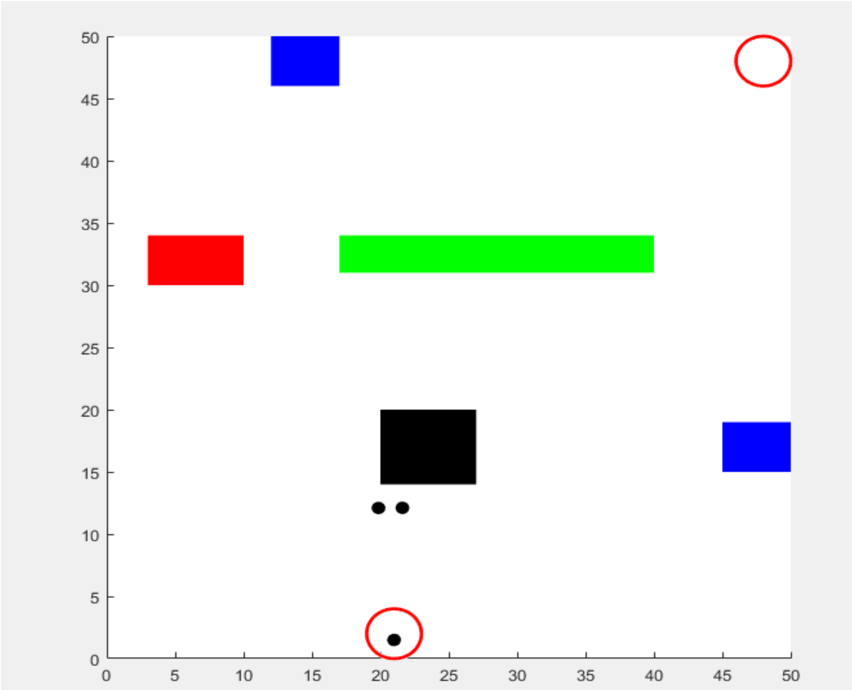


Fig1

Here,fig 1 shows the above result.Since there are no pheromone previously deposited,so the two robots takes random path.One goes right(1st robot) and the other goes left(2nd robot).

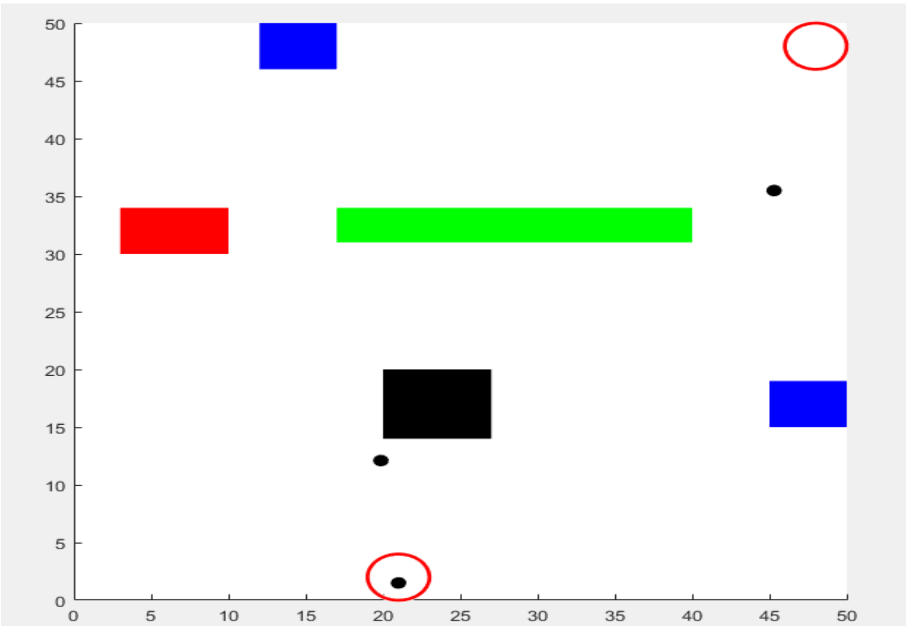


Fig2

Fig2 showing that the 1st robot takes the right path toward the destination.

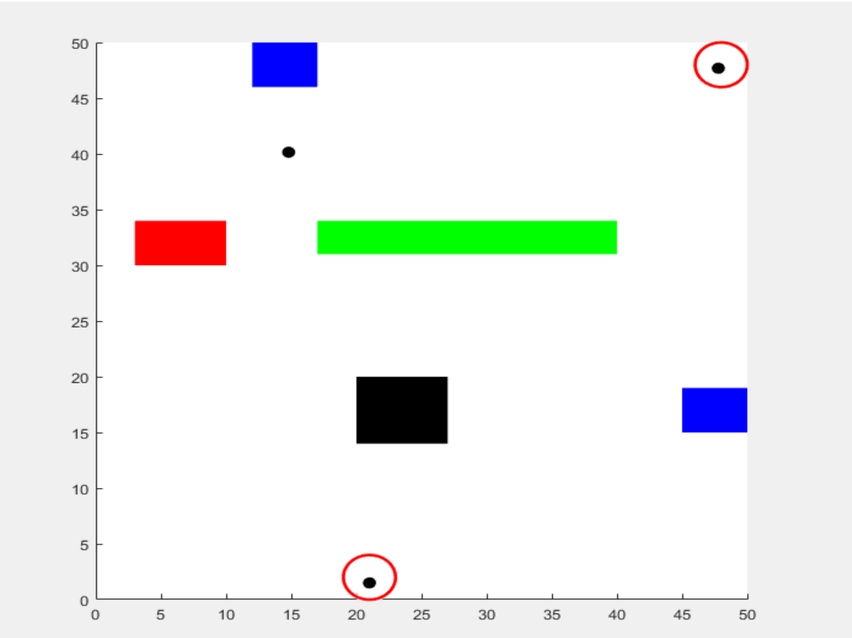


Fig3

Fig3 shows that,while the 1st robot has already reached the destination, the 2nd robot is in its midway path.

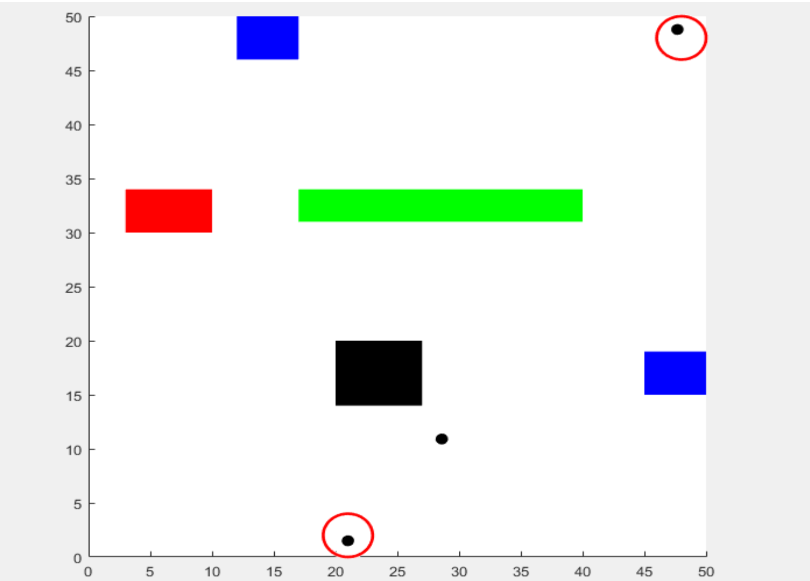


Fig 4

Here,figure 4 shows that while the 1st robot tends to reach the source station back,the 2nd robot just reaches the destination point.So,clearly the pheromone deposited till now will be higher on the right path.

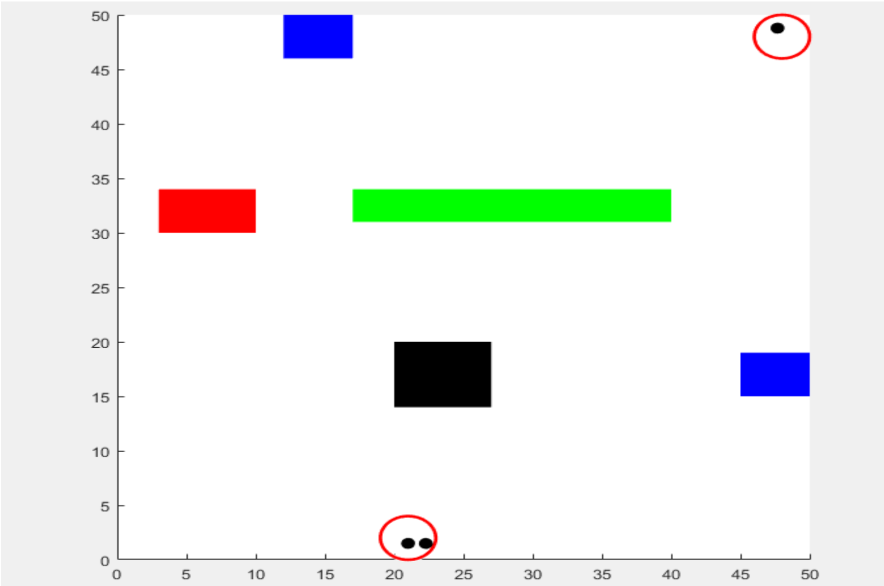


Fig5

This fig displays that the 1st robot has reached back the source point.

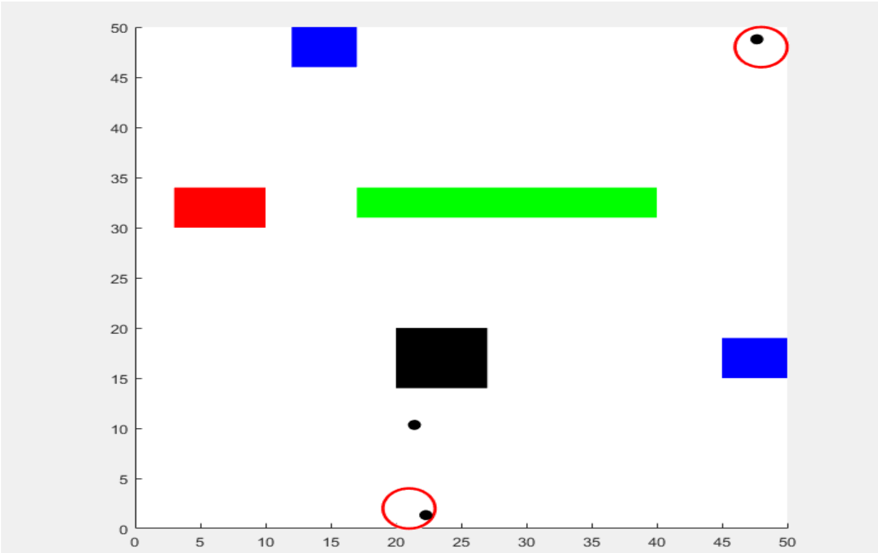


Fig 6

Now the 3rd robot goes out of the search station to reach the destination point,following the path where higher pheromone has been deposited.

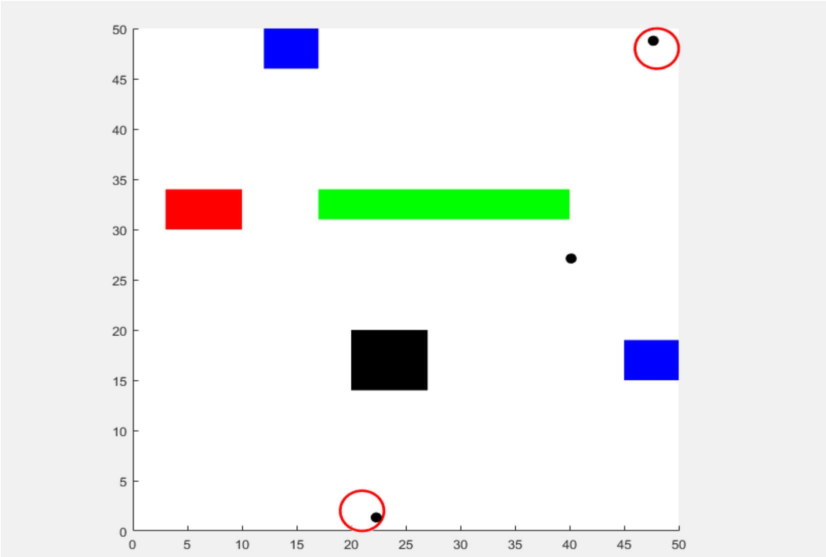


Fig 7

This fig7 explains that since the pheromone level was high on the right hand side,the 3rd robot follows that path to the destination.

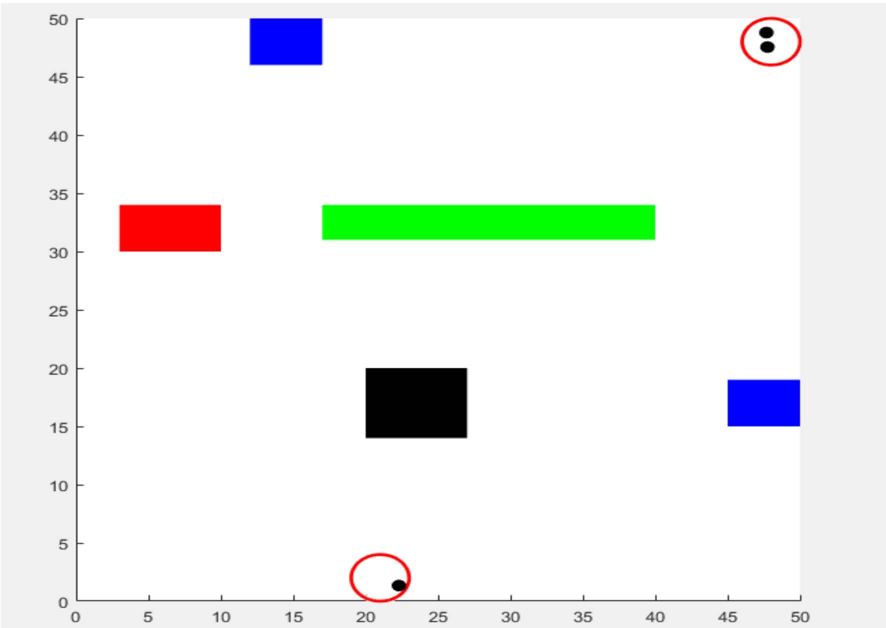


Fig 8

Finally the 3rd robot reaches the destination using the ACO algorithm.

CONCLUSION:

ACO is used to find the shortest navigational path of mobile robot avoiding obstacles to reach the target station from the source station. Basically, in this paper we have focused on the robot swarm foraging using the ACO.

We have seen how the ants travel from a particular base station to a certain aim (assumed to be the loaction of food particles). The main objective was to find out the minimum distance that the ant will follow after a certain number of cycles.

As we know that the ants lefts out pheronome while travelling,so we can find out the minimum distance of the base station to the aim by looking at the pheronome concentration per cycle.

Thereafter all ants will follow that path with shortest distance,also they will avoid the obstacles in their path to reach the desired destination.

Precisely,we have done obstacle avoidance along with the ACO to find out the shortest distance that the ant will follow while moving from base station to the desired aim.

APPLICATIONS OF ANT COLONY ALGORITHM:

In recent years, the interest of the scientific community in ACO has risen sharply. The use of an algorithms providing exponential time worst complexity is often infeasible in practice, thus ACO algorithms can be useful for quickly finding high quality solutions.

Routing problems:- for example, in the distribution of goods

Scheduling problems:- which–in the widest sense–are concerned with the allocation of scarce resources to tasks over time

Applications To Telecommunication Networks ACO algorithms have shown to be a very effective approach for routing problems in telecommunication networks where the properties of the system, such as the cost of using links or the availability of nodes, varies over time. ACO algorithms were first applied to routing problems in circuit switched networks

References

[1] E.H.L.Aarts, J.H.M.Korst, Simulated Annealing and Boltzmann Machines, JohnWiley, 1988.

[2] J.L.Bentley, "Fast Algorithms for Geometric Traveling Salesman Problems," ORSAJournal on Computing, 4 (4), 387-411, 1992.

[3]H.Bersini, F.J.Varela, "The Immune Recruitment Mechanism: a Selective EvolutionaryStrategy," Proceedings of the Fourth International Conference on Genetic Algorithms, Morgan Kaufmann, 520-526, 1991.

[4] S.C.Boyd, W.R.Pulleyblank, G.Cornuejols, Travel Software Package, CarletonUniversity, 1989.

[5] R.E.Burkhard, "Quadratic Assignment Problems," European Journal of OperationsResearch, 15, 283-289, 1984.

[6] A.Colorni, M.Dorigo, V.Maniezzo, "Distributed Optimization by Ant Colonies,"Proceedings of the First European Conference on Artificial Life, Paris, France, F.Varela and P.Bourgine (Eds.), Elsevier Publishing, 134-142, 1991.

[7] A.Colorni, M.Dorigo, V.Maniezzo, "An Investigation of some Properties of an AntAlgorithm," Proceedings of the Parallel Problem Solving from Nature Conference (PPSN 92), Brussels, Belgium, R.Männer and B.Manderick(Eds.), Elsevier Publishing, 509-520, 1992.

[8] A.Colorni, M.Dorigo, V.Maniezzo, M.Trubian, "Ant system for Job-ShopScheduling," JORBEL - Belgian Journal of Operations Research, Statistics and Computer Science, 34, 1, 39-53.

[9] A.Colorni, M.Dorigo, F.Maffioli, V.Maniezzo, G.Righini, M.Trubian, "Heuristicsfrom Nature for Hard Combinatorial Problems," International Transactions in Operational Research, in press.

[10] J.L.Deneubourg, J.M.Pasteels, J.C.Verhaeghe, "Probabilistic Behaviour in Ants: aStrategy of Errors?," Journal of Theoretical Biology, 105, 259-271, 1983.