Application of Ant Colony Optimization for finding Navigational Path of mobile robot

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By

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CERTIFICATE

This is to certify that the work in this thesis entitled **Application of Ant Colony Optimization for finding navigational path of mobile robot** by **Shakti Prasad Roul** has been carried out under my supervision in partial fulfillment of the requirements for the degree of **Bachelor of Technology** in **Mechanical Engineering** during session 2010 – 2011 in the Department of Mechanical Engineering, National Institute of Technology, Rourkela.

To the best of my knowledge, this work has not been submitted to any other University/ Institute for the award of any degree or diploma.

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Abstract

In this paper, we apply the meta heuristic method of Ant Colony Optimization algorithm on an autonomous mobile in a grid model with a static obstacle. The robot is placed at the bottom left corner of the grid and the target station is at the upper right corner of the grid. The mobile robot has to reach the target station avoiding collision with the obstacle in an optimum path. Simulation is done using MATLAB.

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CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 Path Planning

Path planning of robot refers to the determination of a path, a robot takes in order to carry out the required task with a given set of input parameters. It is one of the most important functions of mobile robot. To find optimal path from source station to target station, that reduces time, cost and distance, in an unknown environment, avoiding collision with obstacles is a topic of great interest to research scholars. Since it is an area of great practical application, different algorithms are proposed. Path planning or robot navigation can be done in static as well as dynamic environments. In case of static environment, the position of the obstacle (if any) is fixed and does not change with time. However in case of dynamic environment, the position of the obstacle changes with time. In case of robot navigation, a mobile robot reaches the target destination from source station, without any human interference, avoiding collision with obstacles and upon iterations gives an optimal path. Path planning can be classified into two categories [11]: global path planning and local path planning. If the robot has prior knowledge about the environment it is called global path planning. It is done in offline mode before the robot starts to move. If no prior knowledge about the environment is present the robot has to sense the presence of obstacles and make a decision about its movement towards the target station avoiding collision, it is called local path planning. It was introduced to solve mobile robot path planning problem in presence of obstacles in the environment. It is done online when the robot avoids obstacles in a real time environment. This paper is focused on navigational path of a mobile robot in a static environment, where the robot has to reach the target station avoiding collision with obstacles present in its path. The algorithm proposed in this paper is based on the foraging behavior of real ants i.e. using Ant Colony Optimization algorithm.

1.1.2 Ant Colony Optimization

Ant colony optimization algorithm is a Meta heuristic approach proposed by M. Dorigo et.al in 1992 as a solution to solve optimization problems. It is based on probabilistic technique and gives optimum solution through graphs. It is inspired from the foraging behavior of real ants. When searching for food, ants move randomly in different directions. They release a chemical substance called 'pheromone' along the path they trace on their return trip. The amount of pheromone deposited depends on the quality and quantity of the food. This pheromone evaporates with time. After a certain interval of time, the concentration of pheromone is greater along the shortest path as the ant makes more number of trips compared to others. The higher concentration of pheromone attracts other ants and thus each one make it along the shortest path from nest to food source. This sort of indirect communication between species is called "stigmergy" :[12] this concept was first introduced by French biologist Pierre-Paul Grasse in 1959. With stigmergy, ants communicate among themselves by modifying their local environment. This characteristic of real ants is used in artificial ants to solve optimization problems. Ant Colony Optimization (ACO) algorithms, initially aimed to search an optimal path in a graph, have been applied to solve many combinatorial optimization problems.

In case of any obstacles present in their path, ants move along the contour of the obstacle on either ways and find their way to the food source, the concentration of pheromone being greater along the shorter path as the ants accumulate more pheromone in a given time interval along the shorter path. All ants move at approximately the same speed and deposit pheromone at the same rate. Ants prefer a higher pheromone trail level that makes the accumulation quicker on the shorter path.

1.1.3 Artificial Ants

In this work, artificial ants (or simulation agents) are the mobile robots that are inspired from the real ants. The movements of the artificial agents are governed by a probabilistic function that depends on both the pheromone concentration along the path as well as a heuristic function. They move through a parameter space having all possible solutions and generate optimal solutions. Artificial ants prefer paths having higher pheromone concentration. The position of ants and quality of solution is recorded so that better solutions can be obtained in later simulation iterations.

1.2 Aims and Objectives:

The aim of the thesis is to find an optimum path of an autonomous mobile robot between two stations using Ant Colony Optimization algorithm. So as to create a real time environment for the robot we use a grid map. A static obstacle of rectangular shape is placed in between the two stations. The objective for the robot is to reach the target station from the source station avoiding collision with the obstacle. After several iterations, it is found that all the artificial ants move along a common path that gives the optimum solution.

1.3 Outline of the thesis:

The thesis is divided into five chapters:

- Following the introduction, chapter 2 is dedicated to a review of the literature on mobile robot as well as Ant Colony Optimization algorithm.
- Chapter 3dealswith the analysis part of the thesis i.e. about the problem statement as well as the proposed solution.
- Chapter 4 discusses the result obtained.
- Chapter 5 summarizes and concluded the research.

Chapter 2

LITERATURE SURVEY

2. **Literature Survey**

O. Hachour[1] proposed algorithm for path planning of autonomous mobile robot in an unknown environment. An autonomous robot reaches the target station avoiding collision with static obstacles. The robot travels within the environment sensing and avoiding obstacles that come across its way to the target station. Optimal path that would minimize cost, time, energy was planned when the mission was executed. The proposed algorithm was implemented in Borland C++ since it is suitable for graphic problems, afterwards tested with Visual Basic and DELPHI language .. The simulation is an approach to the real expected result. This navigation approach has made the robot able to achieve : to avoid obstacles, perception, deciding and to attend the target.

Daniel Angus [2] 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. The visibility is the parameter that is intended to influence each ant to move towards the target vertex in a minimum straight line distance. Visibility is problem specific. The possibility of traversing a probable edge based on visibility is given by :-

$$\text{Visibility} = \frac{\text{distance from current position to target vertex}}{\text{distance from possible position to target vertex}}$$

Initially each edge is assigned with a particular pheromone value. The pheromone concentration evaporates with time and is updated after each tour in accordance with given formulas.

The probability of selecting a path based on cost considerations is given by:

$$\text{Probability} = 1/2^{cost}$$

The probability for selecting a path taking into consideration all the three parameters is given by:

$$\text{Probability} = \frac{(\text{Pheromone})(\,1/2^{cost})(\text{visibility})}{\sum(\text{Pheromone})\,(1/2^{cost})(\text{visibility})}$$

Initially it is required for the ants to search the entire space and finally converge to an optimum solution .

M.Dorigo, C. Blum[3] 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. They also discussed the relation between Ant Colony Optimization algorithm and other approximate methods for optimization. Finally they discussed research works related to the Ant Colony Optimization algorithm giving a better understanding of its behavior and application.

Shahram Saeedi and Iraj Mahdavi[4] formulated a mathematical model to obtain the shortest path using Ant Colony Optimization. The model required calculation of shortest path between source to target minimizing cost in the absence of any obstacle. The ants start their journey from nest to food. At each node, the ant has to chose the succeeding node from the probable options available. The choice is based on the pheromone concentration on each arc connecting the two nodes. Higher the pheromone concentration, higher is the probability of selecting the arc. Evaporation of pheromone is taken into account after the ant makes a complete loop and reaches the source station. The model was programmed in C language and was run for 2000 artificial ants several times.

Vinay Rishiwal et al. [5] 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. Each color is associated with a distinct penalty value for a region on terrain map with respect to the constraint under consideration. Using ACO an artificial ant was simulated to search an optimum path between source and target station. The ant selects the succeeding node to visit from the list of probable nodes based on transition probability and directional biasing. Transition probability maintains a balance between pheromone intensity and heuristic information. The next node is selected on the basis of maximum probability and the process is continued till target station is reached. The directional probability increases the chances to select the next node that is in the direction of destination.

Yee Zi Cong et al. [6] solved the mobile robot path planning problem using ACO algorithm. To establish the effectiveness of ACO in solving mobile robot path planning problem, several maps of different complexity used by an earlier researcher was used for evaluation. Each map consisted of static obstacles in different orientations. Each map was represented in a grid form with equal number of rows and columns. The mobile robot placed at the starting node finds its way towards the destination avoiding all the obstacles on its way. A number of iterations were performed and the shortest route was found. Several assumptions were made in applying the ACO meta heuristic to the mobile robot path planning problem. Firstly, only one ant was sent to explore the map. Also the ants were allowed to move only one node at a time i.e downwards, upwards, rightwards or leftwards. Apart from that each ant can travel to a node only once. When one ant encounters a dead end (no more possible move), it is killed off and another ant is deployed. The heuristic function was also modified in this case. Since each ant was allowed to move one step in any of the four directions with distance being the same in all the cases= 1, the heuristic function which is the inverse of the distance is also same in each case. Hence it is considered redundant. Each node is given an initial value of heuristic information, similar to pheromone. However, unlike the pheromone, it does not evaporate. It is updated in a method similar to that of the pheromones. The results obtained from the proposed algorithm were compared with those of the referred research papers. Analysis revealed better results were obtained in this case with the assumed modifications than in the previous cases.

Song-Hiang Chia et al. [7] 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. At each node, the robot has eight possible directions: north, south, east, west, north-east, north-west, south-east or south-west.

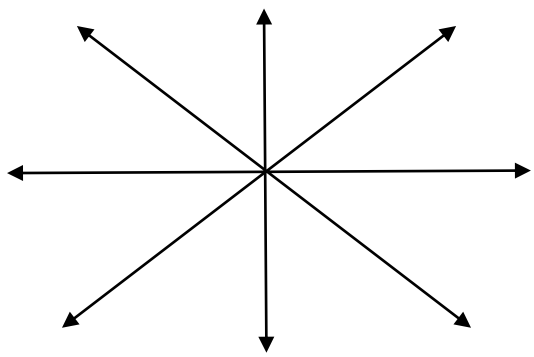

Fig 1 motion direction of the ant

The experiment was performed in a rectangle of 20X20 grids. Each node moved to was stored in the memory and hence visited once only. Obstacles of various shapes were used and optimum results were obtained in each case.

Michael Brand et al. [8] applied ACO to robot path planning in a dynamic environment. They made a comparison between the two different pheromone re-initialization schemes. They also presented the computer simulation results. The proposed ACO algorithm was applied for robot path planning in a grid network. The simulation was coded in python. In the simulation, three different sizes of grid network were considered. In the proposed algorithm it was assumed that one ant can move to one of its adjacent node in four different directions, i .e left, right, up or down. Thus distance between two successive nodes was same. Firstly simulation was done for environment without obstacles. Next obstacles were added and pheromones in the network are re- initialized. Two different re-initialization plans, namely, the global initialization and the local initialization were used, tested and their performances were compared.

Buniyamin N. et al. [9] presented an overview of mobile robot path planning algorithms for autonomous robots. They also focused on the bug algorithm family which is a local path planning algorithm. Bug algorithms exploits sensors to detect any obstacle present on the path of the mobile robot towards target station , with limited information about the environment. The proposed algorithm makes use of obstacle border as guidance towards the target as the robot circumnavigates the obstacle till it discovers certain condition to fulfill the algorithm criteria to avoid the obstacle towards the target point. The robot is able to scan the entire environment with sensors that allows it to rotate itself from 0° to 360°.They also introduced an approach utilizing a novice algorithm called PointBug. This algorithm minimized the use of outer perimeter of an obstacle by searching for points on the outer perimeter of obstacle area as a turning point to target and eventually generates a complete path from source station to target station. The initial position of robot heading straight towards the target point and then it rotates left or right searching for sudden point. After the first sudden pint was observed, the rotation of the mobile robot is in accordance to the position of d_{min} line where d_{min} is the shortest distance between sudden point and target point in a straight line. Its value is recorded each time the robot reaches new sudden point. The mobile robot neglects sensor reading at 180° rotation to avoid detection of preceding sudden point. If no sudden point is found within a360° rotation, the robot stops immediately. This algorithm produces shorter total path length taken by a mobile robot. This approach was compared with other existing local path planning algorithms for total distance.

Ritesh Maurya et al.[10] solved the mobile robot path planning problem using both generalized and modified ant algorithm. In case of simple ant colony algorithm, ant selects its succeeding node from the eight possible nodes. But in case of the modified algorithm ant selects its succeeding node either from 16, 24 or 32 neighbor nodes. Thus with the increase in neighbor nodes, more optimal solutions in terms of path length are obtained. However this also leads to increase in execution time. Simulation was done in MATLAB. With increase in level of generalization, it was concluded that the path length obtained was shorter. However the level of generalization cannot be increased beyond a certain limit as the execution time is also increasing.

Nohaidda binti sariff et al. [11] proposed an accurate representation of heuristic and visibility equation of state transition rules to maintain the ACO algorithm for solving mobile robot path planning of finding the optimal path. ACO technique is used in designing the path for robotic navigation system in static as well as dynamic systems where the path can be of two types one being the global where the path is determined offline to be traversed by the robot in the real environment to opt for the optimal one like the ant searching for its food in the colony and the other is local where path design is usually done online in addition the robot has to overcome obstacle on its way to the destination .The computational efficiency was evaluated by time, distance and the number of iteration taken to determine its optimal path. An environment was designed as a map that contains the initial nodes as input and final nodes along with the area for obstacles. Nodes were represented in x-y coordinate while the location of the robot's move gives the actual distance to optimize the feasible free space path to the goal. The robot didn't traverse the obstacle area .The environment simulated the colony of ants where the ants safely traverse their way to the food. Finally the performance evaluation and optimal path determination was the basis for effectiveness for path planning for robots.

M.A Porta Garcia et al.[12] proposed a new method SACOdm to solve the navigational problem of mobile robot which is based on Simple Ant Colony Optimization Meta Heuristic (SACO-MH). In the name of the new method d stands for distance and m stands for memory. The probability formula was modified that included the distance parameter with weightage β varying from 0 to infinity. Another parameter γ was added to enhance the memory capacity of the robot which keeps track of the visited nodes. The solutions obtained made the proposed method a promising one for robot navigation. The execution time was decreased drastically.

Jie Donget et al.[13] proposed an improved algorithm for autonomous robot obstacle avoidance. The execution time to obtain optimal solution is high as ants choose path randomly in the beginning in search of food. After a number of iterations we obtain the optimum path. Normally ants select the path based on pheromone level and visibility. Another parameter, the heuristic function is included to make the execution time lesser.

Chapter 3

ANALYSIS

3. Analysis

3.1 Problem Statement:

We select a 2-D grid model to represent the environment of the mobile robot. The map consists of a 100x100 square grid of uniform pattern of grid points. The X-axis is divided equally into 100 parts and the Y-axis is also divided into 100 equal parts. The edge of each cell is of unit length. The origin or the source station of the robot is at the bottom left corner with coordinate (0, 0). The target station of the robot is at the top right corner with coordinate (100, 100). An obstacle of rectangular shape is placed in the environment of the robot with coordinates (70, 70) and (90, 90) as diagonal. The mobile robot has to reach the target station from the source station avoiding collision with the obstacle in an optimum path using Ant Colony Optimization algorithm.

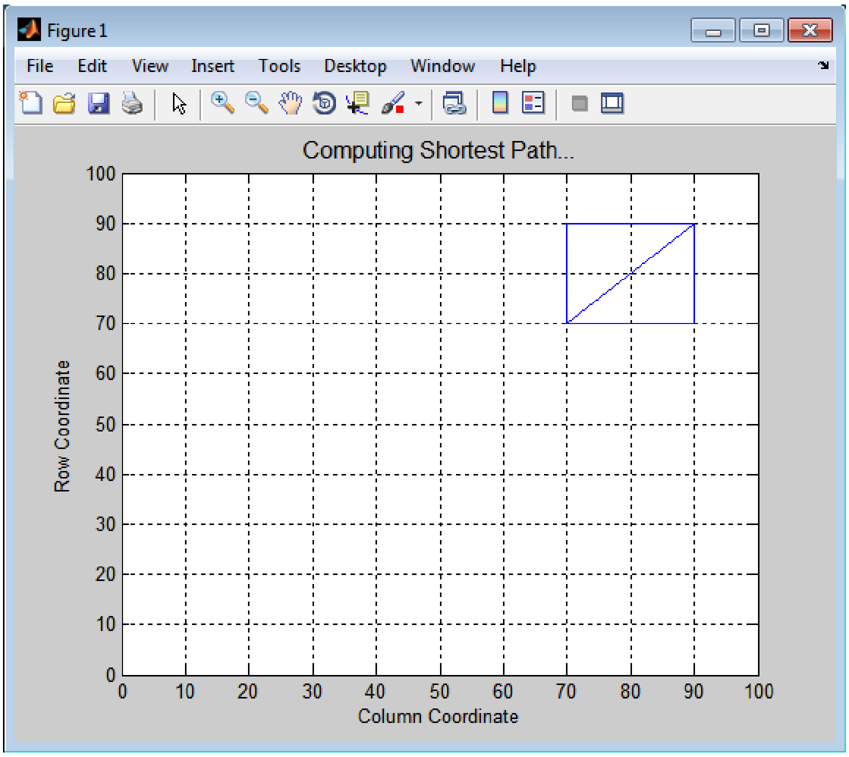

Fig 2. Grid model for the problem

3.2 Proposed Solution:

The mobile robot placed at origin (0, 0) selects its succeeding node on the basis of the probability formula used in ACO algorithm which is as follows:

$\text{Probability}_{ij}^{k} = (\tau_{ij}^{k})^{\alpha}(\eta_{ij}^{k})^{\beta} / (\sum(\tau_{ij}^{k})^{\alpha}(\eta_{ij}^{k})^{\beta})$……………….eqn 1

where pheromone intensity is denoted by τ_{ij}^{k}. As with real ants, the higher the pheromone level on a path, the more probability that the artificial ant will take the path. The summation in the denominator takes into account all the possible choices of succeeding node (or neighboring nodes) when the ant is at node i. Both α, β weigh the importance of the pheromone and heuristic value respectively. η_{ij} represents the heuristic information which is given by the inverse of the distance between i,j.

Initially all the nodes are assigned with same pheromone values. So the heuristic function plays the primary factor that determines the probability. Nodes that are closer to the robot have a higher probability of being selected. In this way the robot moves in the search space till it encounters an obstacle. When the succeeding node for the robot is coincident with the obstacle boundary, it is not considered as a feasible node and the robot rotates such that it perceives a viable node. The procedure continues till it reaches the target station. The pheromone intensity of the path evaporates with time. After pheromone evaporation occurs, the new pheromone levels are updated with the extra pheromone laid by the ant(s) that just crossed the path [8] in accordance with the formula given by:[13]

$$(\tau_{ij})_f = (\tau_{ij})_i (1-\rho) + \sum_{k=1}^{m} Q/L^K \text{……….eqn2}$$

Where ρ= decay constant

τ_i = initial value of pheromone

τ_f = final value of pheromone

Q= number of nodes crossed

L^k= path length traversed by ant k

The updated pheromone level is now used by the succeeding ant in the calculation of probability and the process repeats. For each ant we calculate the distance traversed and get the best value upon comparison. For successive iterations, the pheromone value is changed and process repeated. If we increase the number of ants in each iteration and repeat the algorithm, eventually we will get all the ants to move along a common path that happens to be the optimal solution.

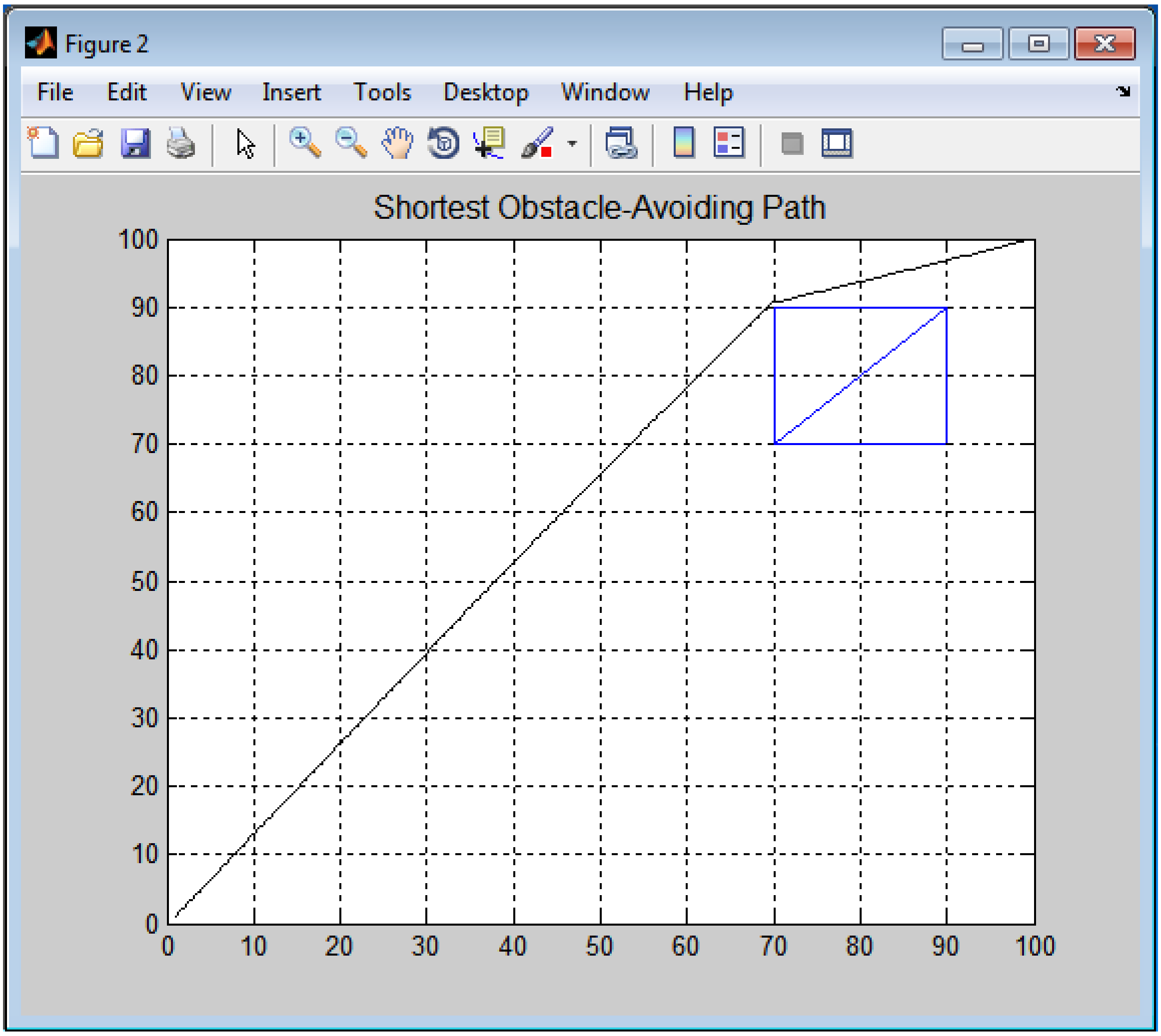
Figure 2
File Edit View Insert Tools Desktop Window Help
Shortest Obstacle-Avoiding Path
100
90
80
70
60
50
40
30
20
10
0
0 10 20 30 40 50 60 70 80 90 100

Fig. 3 Output

Chapter 4

DISCUSSION

4. Discussion:

The ants initially travel in different directions on each successive iterations. It is assumed that ants can travel only in eight directions namely: north, south, east, west, north-east, north-west, south-east and south-west. With update in pheromone intensity after each complete tour to target station, a new path is obtained. When we increase the number of iterations it is seen that all the ants travel in common path that gives the optimal solution for the given problem. Simulation is done using MATLAB. Experimental details are as shown in fig[3]. The outcome of the experiment confirms the objective and gave effective solution. It travels diagonally along the shortest path towards the target and at edge of the obstacle it deviates and changes its path. Different path will be generated when pheromone initializations as well as value of other parameters are changed.

Chapter 5

CONCLUSION

5. Conclusion:

To find the navigational path of robots is currently among the most
Intensively studied and promising area of research which has a significant role in robotics. It has varied application in different field of works, especially where human presence is dangerous, to avoid human error or economically not viable. In this paper, ACO is used to find the shortest navigational path of an autonomous mobile robot avoiding obstacles to reach the target station from the source station. The output is found to be optimal and satisfying for the given problem. With increase in complexity of the problem, i.e. with increase in number of obstacles or in dynamic environment, the Ant Colony Optimization Algorithm can be applied effectively giving optimal path in lesser time.

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