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Development of an Ant Colony Optimization Technique for Solving Robot Routing Problem

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Abstract: *Path planning has been one of the major research challenges in a Mobile Robot navigation system. Researchers in this area have recorded significant success. However, there are still research issues. Ant Colony Algorithm (ACO), an intelligent optimization Algorithm has recorded successes in many domains including robot control. In this work, ACO was used to find solutions to the robot routing problem. Simulation results established that the proposed algorithm outperformed the min-max ant system technique.*

Keywords: Mobile Robot, Routing, optimization, Ant Colony, Simulation.

I. INTRODUCTION

The Robot Routing Problem (RRP) is a computational problem to find a sequence of valid configurations that moves the object from the source to the destination. It generalizes the well-known traveling salesman problem (TSP). The Vehicle Routing Problem (VRP) is a generic name given to a whole class of problems in which a set of routes for a fleet of vehicles based at one or several depots must be determined for some geographically dispersed cities or customers. Due to the nature of the problem of VRP, it is not possible to use exact methods for large instances of the VRP [1]. Amin and Ahmad in 2015, suggested an algorithm based on Ant Colony System and searched two goals with finding paths with the minimum number of vehicles and minimum time of costumers, service [2].

The shortest routes between any two points in the system are given and a demand for one or several products is specified for some stations within the distribution system. It is desired to find a way to assign stations to trucks in such a manner that station demands are satisfied and total mileage covered by the fleet is a minimum.

This article presents an ant colony optimization (ACO) approach to provide novel solutions to the Robot path planning problem (RPPP) by simulating the behavior of ant colonies in nature as they forage for food and find the most efficient routes from their nests to food sources. The decision-making processes of ants are embedded in the artificial intelligence algorithm of a group of virtual ants which are used to provide solutions to the robot routing problem. This approach is relevant because it provides solutions to an important problem in transportation science and the experimental results indicate that the performance of the technique is competitive with other techniques used to generate solutions to the RRP. The objective of this project is to design and simulate an Ant Colony Model for solving Robot Routing Problem (RRP).

II. SYSTEM ANALYSIS AND DESIGN

The development of an ant colony optimization technique for solving the Robot Routing Route Problem is aim at using the ant colony optimization (ACO) approach to find solutions to the vehicle routing problem (VRP) [3]. ACO simulates the behavior of ant colonies in nature as they forage for food and find the most efficient routes from their nests to food sources [4]. The decision-making processes of ants are embedded in the artificial intelligence algorithm of a group of virtual ants (Mobile Robots) which are used to provide solutions to the vehicle routing problem. This approach is relevant because it provides solutions to an important problem in transportation science. The structure, flow chart, and design algorithms of the work are discussed in this section:

2.1 Methods

This project focuses on the traversing action of intelligent e-puck robotic agents (artificial ants). An Ant-based controller was developed to control the robot's movement from one point to the other optimizing cost (distance and time). E-puck robots carry out the specific task of traversing their environment and avoiding obstacles. The ACO approach of solving the RRP involves two processes namely:

- Route Construction
- Signal-Drop Updating

2.1.1 Route Construction

Illustration I: Consider the Traveling Salesman Problem (TSP) as shown in Fig 1. TSP is a problem that one salesman has to visit all the cities and find the shortest path.

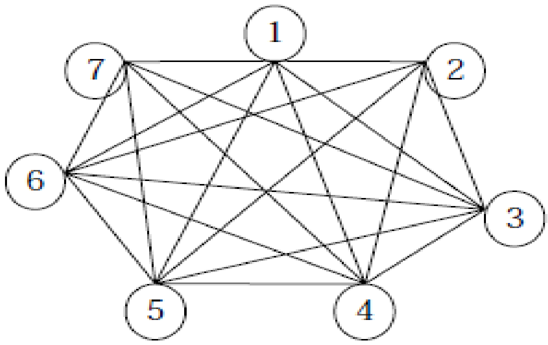

Figure 1: TSP Model

An artificial ant is an agent (robot in the case of this project work) which moves from city to city (i.e moving from one point to another point) on a TSP graph. It chooses the point to move to use a probabilistic function both of accumulated signal-drop on edges and of a heuristic value, which is chosen as a function of the edge's length. Robots probabilistically prefer points that are connected by arcs (edges) with a lot of accumulated signal-drop and which are close by.

2.1.2 Signal-Drop Updating

Illustration II: Initially, *m* robots are placed in randomly selected positions (representing the depot i.e the starting point). At each time step, they move to a new position and modify the signal-drop value on the edges used. This is called local signal-drop updating. When all the robots have completed their tours, the robot that uses the shortest tour is selected and the edges belonging to its tour are modified. It is called global signal-drop updating, by adding an amount of signal that is inversely proportional to the tour length. These are three ideas from natural ant behavior that we have transferred to our artificial ant (robot):

- The preference for paths with a high signal level.
- The higher rate of growth of the amount of signal on shorter paths.
- The signal-drop communication among robots.

Robots can determine how far away points are from one another, and they have a working memory (M_k), a TABU list, used to memorize points already visited.

Each robot acts as a salesman. They have a memory (the working memory is emptied at the beginning of each new tour, and is updated after each time step by adding the new visited point), a buffer which will record the sequence of the visited locations, called Tabu List. These robots are randomly placed on the locations, which are the first locations in the Tabu list of these robots.

2.3 System Architecture

The ant colony optimization (ACO) algorithm for vehicle routing problem (VRP).

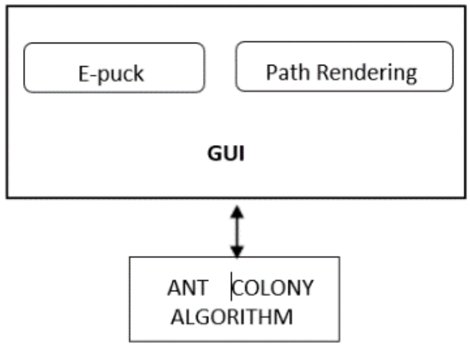

Figure 2: Architectural Diagram of the ACO model for solving VRP

The following characteristics are present in all ACO algorithms:

- the use of a colony;
- the cooperative behavior mediated by artificial pheromone trails (signal-drops);
- the probabilistic construction of solutions biased by artificial pheromone trails (signal-drops) and local heuristic information;
- the pheromone (signal) updating guided by solution quality;
- the evaporation of pheromone trails (signal-drops).

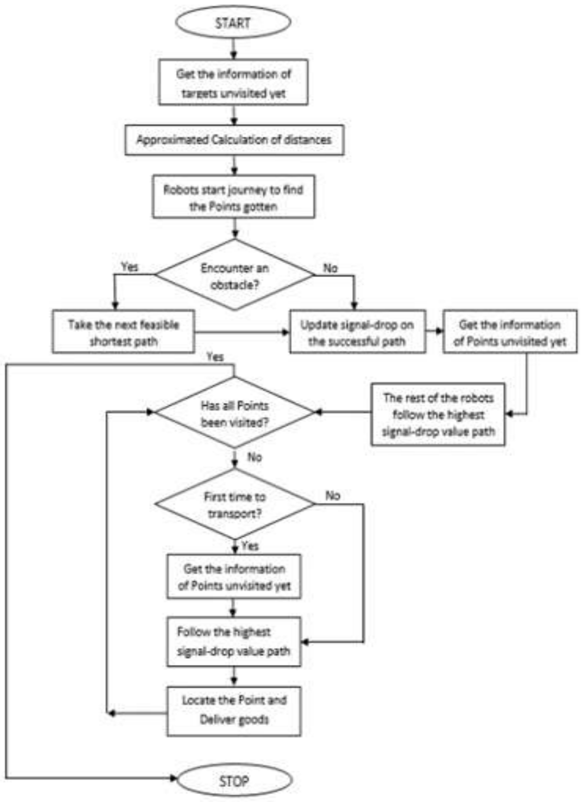

Figure 3: Dataflow diagram of the ACO model for solving VRP

III. SYSTEM IMPLEMENTATION

The control code was coded using Microsoft Visual Studio 2017 with C++ programming language while Ant Colony Implementation (ACI) simulator was used for simulating the experiment.

Figure 4 depicts each point to be visited by robots, all the points are 22 in number as specified before the Apply button is clicked in the order of the visiting from point A to V.

The simulation is being activated to showcase when the Run button is clicked upon, the number of robots to complete the journey, and also the number of points (representing cities) that the simulated robots can visit are dynamically determined. As shown in the snapshot below, 22 points were specified in the simulation to be visited by the robots, and of course, it can always be changed to any number of points. Each point represents a city to visit.

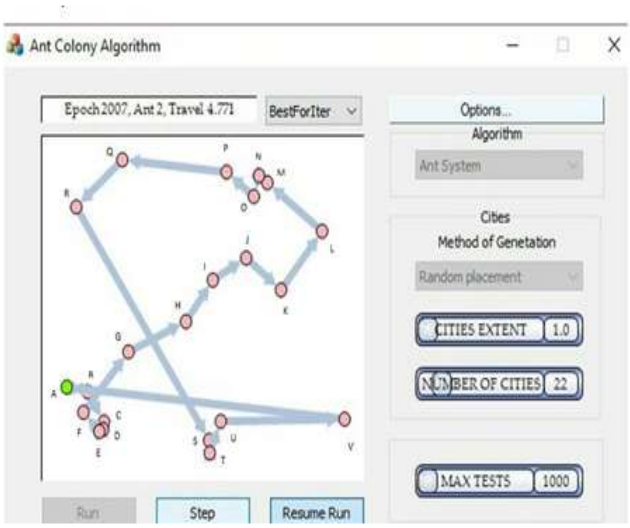

Figure 4: Snapshot of the simulated points visited by robots

Figure 4 shows the movement of the robot from point A to point B which is the nearest to it, and this is determined with the help of the ant colony algorithm that has been programmed on the robot to decide with (that's the ant colony algorithm is serving as the brain of each robot.

After the completion of the route from point A to B, then the next nearest point is C and it is visited next after point B.

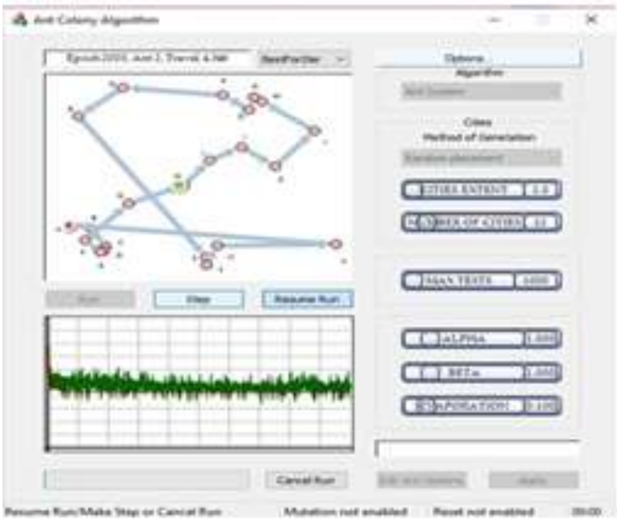

Figure 5: Robot route visitation at the point H

Figure 5 shows the snapshot showing the visitation of robot at the point H. The route/journey continues until all the points are visited, and the last point to visit from figure 5 is point V.

Figure 6 shows the "Develop Section" of the Visual Studio which reveals the codes that are tested to bring about the vehicle routing that is connected to run with the ACI simulator.

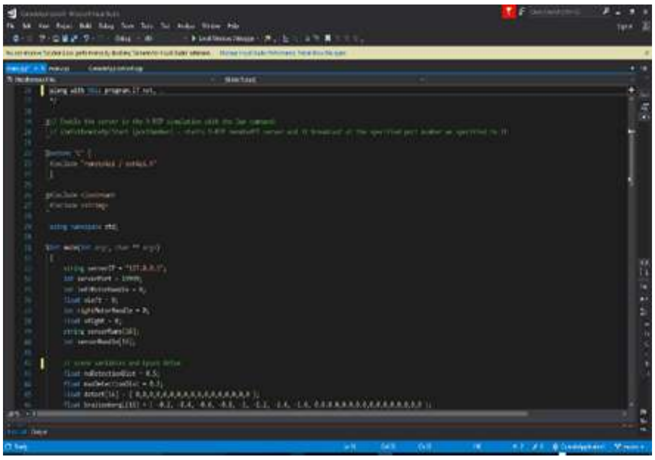

Figure 6: Snapshot of the code controller on the Visual Studio environment

From figure 6, which is the coding interface of what is being developed, the simulation page displays it the way it is tested and the way the routing problem is being solved with the ant-based controller system developed.

IV. RESULT AND DISCUSSION

Following the Ant Colony Optimization technique, this research was able to achieve its objective to design and simulate an Ant Colony Model for solving Vehicle Routing Problem (VRP). The simulation of ten different iterations, comparing run time of ant colony optimization technique to the min-max ant system technique. This result reveals that the ACO technique outperforms the min-max ant system technique.

The simulation results shown in Table 1 and Table 2, reveals that the result obtained from the Ant Colony method is more optimal than the other method we compared it with as the time taken to complete the total route (distance) has always been minimal at each iteration in the case of ACO.

Table 1: Runtime Analysis of Ant Colony Optimization (ACO) for solving Vehicle Routing Problem.

SIMULATION ID	NO OF CITIES	NO OF ROBOTS	TOTAL DISTANCE COVERED (m)	TOTAL TIME TAKEN (ms)
0	22	5	0.110	0.043
1	10	2	0.080	0.031
2	5	1	0.075	0.028
3	40	9	0.123	0.048
4	18	4	0.100	0.037
5	27	6	0.090	0.033
6	12	3	0.076	0.029
7	34	7	0.115	0.039
8	30	6	0.118	0.040
9	25	5	0.111	0.039

Table 2: Runtime Analysis of Min-Max Ant System Algorithm for Solving Vehicle Routing Problem

SIMULATION ID	NO OF CITIES	NO OF ROBOTS	TOTAL DISTANCE COVERED (m)	TOTAL TIME TAKEN (ms)
0	22	5	0.110	0.068
1	10	2	0.080	0.053
2	5	1	0.075	0.042
3	40	9	0.123	0.075
4	18	4	0.100	0.056
5	27	6	0.090	0.051
6	12	3	0.076	0.049
7	34	7	0.115	0.059
8	30	6	0.118	0.049
9	25	5	0.116	0.039

Therefore, the pheromones updating of ants in the concept of the ant colony optimization was implemented as signal-drops updating by robots that evaporate with count downtime (in microseconds) after the latest robot to pass through a path has completed the route/journey along the path. We have been able to optimize the movement of robots from one point to the other minimizing time taken to complete the traversing, which is the main objective of the project work

V. CONCLUSION

This work has established the use of an Ant Colony optimization technique in solving robot routing problems. The model developed provides an optimum routing of robots in an environment with multi-constraints. The concept of the ant colony optimization was implemented as signal-drops updating by robots that evaporate with count downtime (in microseconds) after the latest robot to pass through a path has completed the route/journey along the path. to optimize the movement of robots from one point to the other minimizing time taken to complete the traversing.

Furthermore, the robots are programmed to avoid obstacles on their paths to the destination. This work opens the doors for a new class of robots to solve vehicle routing problems using the ant colony optimization technique. It is simple, computationally cost-effective, and modular in the sense that they are independent of any specific robot architecture.

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Author Profile

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