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smartPATH:

A hybrid ACO-GA algorithm for robot path planning

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1.Introduction

Robotic has many uses in many fields such as industrial applications, manufacturing, constructions, search, rescue, environment exploration ...etc

Mobile robots' applications have many challenges. One of those challenges is path planning that classified as a major problem. This paper investigates the path planning problem in the context of the RTRACK research project, whose purpose is to design a multi-robot monitoring system by using wireless sensor networks. Path planning aims to path without obstacles for the robot from start to target location. The path must have a set of criteria such as distance, processing time and energy consumption. Path planning can be divided according to robot knowledge about the environment to two classes:

1. The robot has priori information about the environment as a map (known as global path planning).

2. The robot doesn't have priori information about the environment then an estimate map is required (known as local path planning).

There are two type of environments in path planning problem:

- Static environment: The obstacles, goal and start are unchanging.
- Dynamic environment: Locations and obstacles may change over time.

This paper deal with the problem of global path planning in a static environment that accomplish two major contributions:

- Propose smartPATH, a new hybrid ACO-GA algorithm for robot global path planning using powerful mechanisms in the ACO to improve the searching space, search time and solution quality.

- Compare the performance of smartPATH with classical ACO, classical GA approaches and Bellman-Ford shortest path algorithm which show an improvement in solution quality up to 48.3% compared to classical ACO and the execution time up to 64.9% compared to Bellman-Ford.

2.Definitions and Abbreviations

Term	Definition
ACO	Ant colony optimization
GA	Genetic algorithm
IACO	Improved ant colony optimization
WSN	wireless sensor network
CACO	Classical ant colony optimization
SmartPATH WHF	SmartPATH without heuristics function

Table 1: Definitions and Abbreviations

3.Related works

The research for solutions to path planning problems began in the 60s. These solutions can be classified into:

1- **Classical methods**: general methods such as Roadmap, Potential Field, Cell Decomposition and Mathematical programming. These methods have some problems in global optimization, time complexity, robustness etc.

2- **Heuristic methods**: designed to overcome the classical methods. such as Genetic Algorithms, Neural Networks, Tabu Search, Ant Colony Optimization, in addition to several other techniques.

ACO and GA are the most used heuristics techniques in solving the path planning problem. Some other research combining between ACO and GA. The difference with this paper is that this paper using different environments. However, ACO and GA have some problems. The algorithm in ACO will suffer if the size of the problem is large (stuck in local optimum). GA belongs to random optimize processes, so the local convergence problem doesn't appear, this makes its convergence speed slower. Thus, authors of this paper believe that a hybrid ACO and GA approach could be a promising alternative.

This paper proposes a new solution based on a combination of ACO and GA. The solution differs from others because it is using different environment map model based on WSNs. The paths from ACO are taken as an initial population of a crossover operator that avoids getting trapped in a local optimum.

4.Methodology

4.1 Environment Model

To reduce the complexity of problem they used 2D map that contains start point, goal point, obstacles, and free spaces. In addition to sensors that is randomly allocated around the map with (X, Y) coordinates to identify the location .In **Fig.1** the sensors connected with each other constructing a WSN that used to:

1. Locate the mobile robot.
2. Guide the mobile robot to goal destination.

The robot can only navigate between nodes creating sequence of nodes lead to the goal. The connected sensors don't represent a complete graph means If there is no connection between two sensors there is an obstacle.

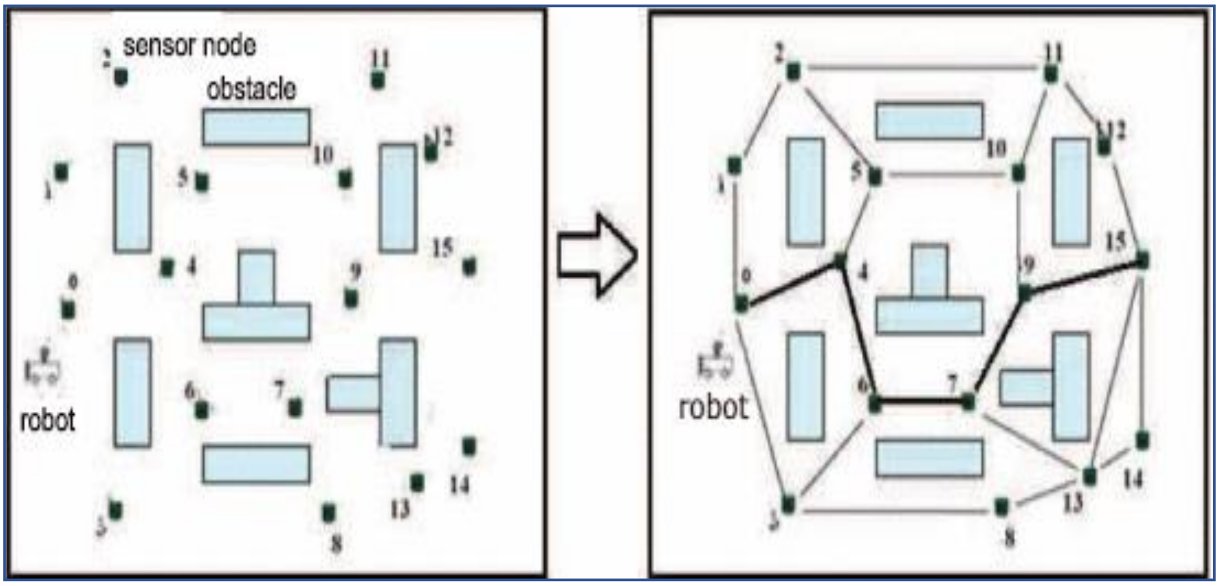

Fig.1: Environment Model

4.2 smartPATH Algorithm

The concept of ACO algorithm is derived from the behavior of the ants in real world, they communicate through pheromones and use it as chemical signals to define the shortest path to the food. GA is also derived from the real world based on the theory of natural selection. The improved ACO is used to find the solution path and pass it to GA that optimize the path.

4.2.1 IACO

The environment is represented as graph and the algorithm generates set of shortest optimal paths from the start point to the goal point, each ant has a position in the graph and can move from one sensor node to another based on the decision it make. And all of this done by three steps:

1- **Path finding:** the ants find the shortest path using two functions that improve making decision about moving to the next sensor node.

- The Heuristic distance information probability: by using heuristic distance information probability in the first iteration to calculate the ant probability of selecting the next sensor node, they avoid the extra amount of time to find the optimal solution resulting of the ant lack of clarity about the next move because in the beginning of the solution the amount of pheromone is low but it doesn't affect the optimal solution by much and this is used in the traditional ACO with transition rule probability function which depends on the pheromone. a modified transition rule probability.

- Modified transition rule probability: used by the rest of iterations define by the formula below

$$p_{i,j}^{k} = \frac{\tau_{i,j}^{\alpha} * D^{\beta}}{\sum_{j \in allowed(i)} (\tau_{i,j}^{\alpha} * D^{\beta})}$$

2- **Path optimization:**

- Early elimination of bad solution and minimize the search space by tracking the ants and when they start to take a bad move comparing with the current best solution they will be ignored since it won't help produce the optimal solution.

- Mutation operator is applied on a path which contain sequence of sensor nodes (the first is start point and the last is the goal) when trying to change the nodes between the start and the goal in the hope of optimize the path by find a shorter one.

3- **Pheromone update:** after each iteration the amount of pheromone is updated from each ant. The path with the most amount of pheromone is likely to be the solution path.

4.2.2 GA

The role of GA is to optimize the current solution found by IACO a local search is applied on the path an attempt to improve it using modified crossover operator that inspired from genetics, the basic idea is to select randomly two paths that have two common nodes, after that creating three sup-parts using the common nodes to separate the paths, then compare all the parts and select the new solution path which has the same number of nodes as the two selected paths but shorter since it contains some repeated nodes [1].

5.Result & Discussion

For testing the hybrid ACO-GA on different type of environment where the number of sensors and obstacles determine the complexity of the environment, they used a simulation with several number of sensors, showing in **Fig.2:** (*a) environment with 16 sensors*, (*b) environment with 27 sensors, (c) environment with 50 sensors and (d) environment 150 sensors*, the more sensors it have the more complex it get.

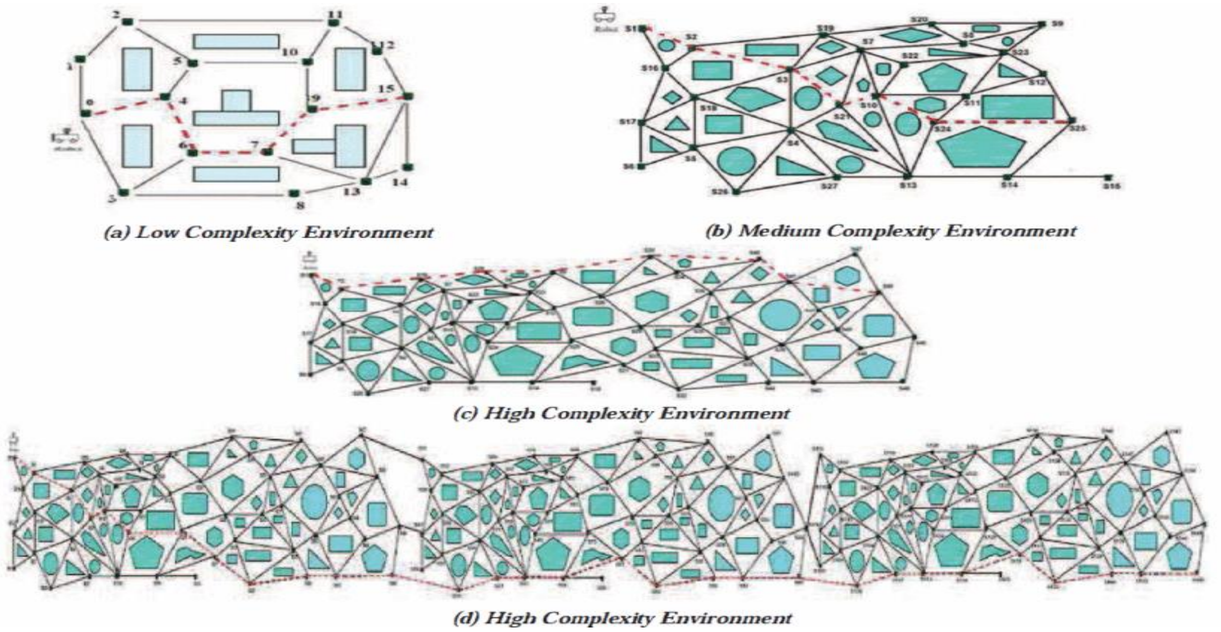

Fig.2: Simulation Environments.

To be able to measure how good is the smartPAHT a comparison with other algorithms and versions of ACO is applied. First classical ACO and GA algorithms, smartPATH WHF (without heuristics function), Improved ACO (without GA part) and the last is a traditional Bellman-Ford. The comparison show what improvement smartPAHT has over other algorithms depending on two criteria: (1) Execution time of the algorithm in each environment, (2) Path length from start to goal (shortest solution). Performed 30 different runs for each algorithm. For each run, they recorded the length of the generated path, the execution time and the index of iteration that corresponds to the best (or optimal) solution [1].

The smartPATH has proven efficiency using the different techniques like reduce the time by ignore the ants that already taking a wrong path, also improve the path using mutation operator after each iteration, and improv the quality of the path solution using GA.smartPATH may take a longer time to produce the optimal solution, Also the number of ants is big part of the solution, the environments 1,2 and 3 tested with 10 ants and the result is showing in **Fig.3** Bellman-Ford, GA and smartPATH has the same path length in the first environment but the execution time of smartPATH is faster, in the environment 4 the number of ants become 20 to be able to produce the optimal solution. As showing in **Fig.4** SmartPATH WHF has better execution time than smartPATH but does not generate optimal solutions which show the benefit of using heuristic function [1].

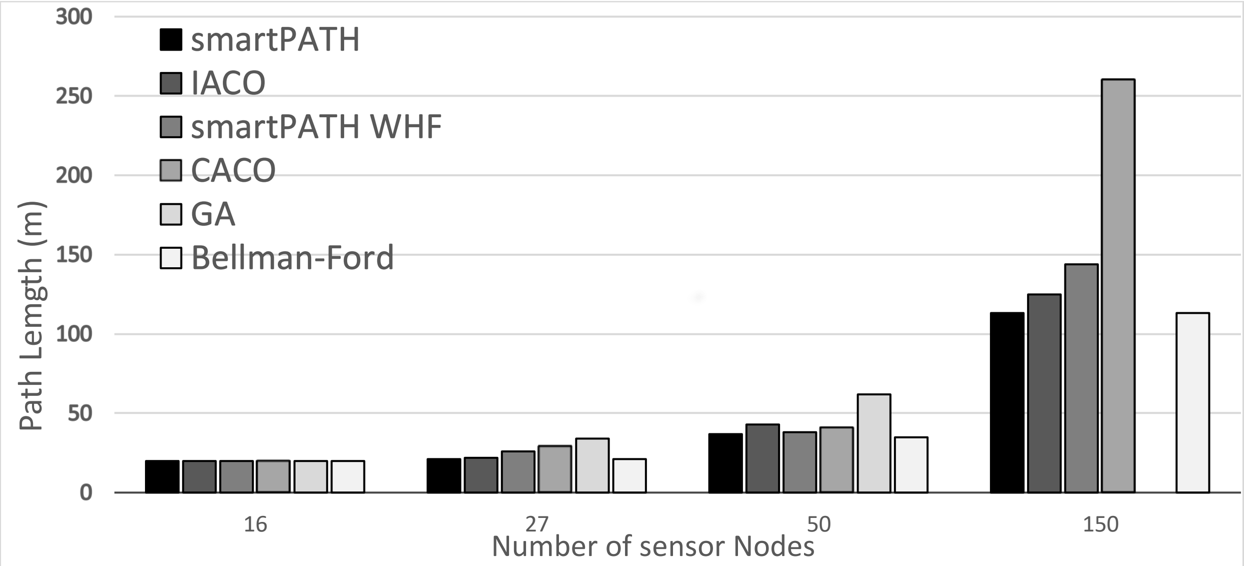

Fig.3: Length of the Generated Paths of smartPATH, IACO, smartPATH-WHF, CACO, GA and Bellman-Ford Algorithms in Different Environments

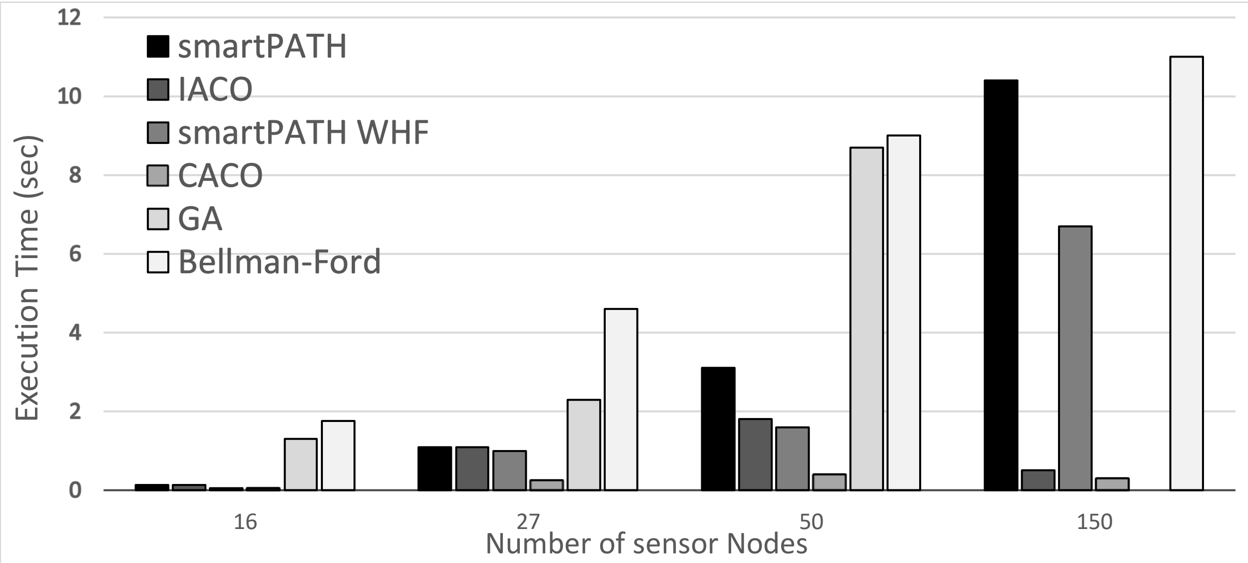

Fig.4: Execution times of smartPATH, IACO, smartPATHWHF, CACO, GA and Bellman-Ford Algorithms in Different Environments

6.Conclusion

Finding the optimal path is very common problem solved by many algorithms and approaches like ACO, GA and Bellman-Ford, but the time and quality of solution is different from on algorithm to another. By combining two algorithm and take advantage of their characteristic a new hybrid ACO-GA algorithm (smartPATH) is developed. by modify the environment to reduce its complexity using WSN that help locate the mobile robot and construct the roads to the goal. The IACO finds paths using heuristics and try optimize the path by using mutation operator and reduce the time by early elimination of the weak ants that take a wrong path, the amount of pheromone left by the ants determine the path to the goal. After sending the path to GA that try to optimize the path using crossover operator the optimal path solution is found. The smartPATH showed great results comparing with other algorithms like an improvement in solution quality up to 48.3% compared to classical ACO and the execution time up to 64.9% compared to Bellman-Ford.

7.References

[1] H. Bennaceur, S. Trigui, K. Al-Shalfan, I. Châari and A. Koubâa, “smartPATH: A hybrid ACO-GA algorithm for robot path planning,” in *2012 IEEE Congress on Evolutionary Computation*, Brisbane, QLD, Australia, 2012.