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Autonomous robot navigation in obstacles based environment

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ABSTRACT

This Article presents an on-line path planning algorithm for autonomous robot's navigation system. Path planning is one of the most important topics in artificial intelligence and robotics navigation field. It can be used in many applications such as autonomous mobile robot navigation, network routing, video game artificial intelligence and gene sequencing.

I propose an algorithm that enables the robot to plan an optimal path from an initial position to a specific goal with a free collision with obstacles and other moving robots. Based on artificial intelligence techniques like A* to find an optimal path for each robot while cooperating with other robots. The optimality of the path can be measured using an objective function that considers the shortest distance, and/or the least time required. The information about the environment is known previously and obstacles are static. Finally, the proposed algorithm results are introduced with many examples and cases.

Keywords: *Path Planning, Optimal Path, Robot, Obstacles, Static Environment, A* Algorithm, Grid Map.*

1. INTRODUCTION

Path-planning is important for autonomous mobile robots that let robots find the optimal path between two points. The main task of the path planning is to make the robot move to the goal without collision with obstacles and other robots. This problem is one of the problems in artificial intelligence. The goal is to make multiple mobile robots system cooperate with each other with free-collision, avoiding obstacles and avoid interference with each other [1]. Path planning is important to find the shortest path to the goal and it needs a map of the environment [2]. The optimality of the path can be measured using an objective function that considers the shortest distance, and/or the least time required. Some of the project applications are "search and rescue, planetary exploration, mineral mining, transportation, agriculture, industrial maintenance, security, surveillance and warehouse management" [1]. Based on A* algorithm we introduce a method to solve the on-line path planning problem by considering obstacles and free collision with other robots.

Different approaches have been presented for implementing path planning for multiple mobile robot system since multiple robot can improve the working capability and performance

[3]. One of the approaches for on-line path planning of multiple mobile robot system is efficient artificial bee colony (EABC) algorithm. The environment is known. "The proposed EABC algorithm enhances the performance by using best individuals for preserving good evolution, the solution provides a proper direction for searching, the update strategy provides the newest information of solution" [3]. Each situation design path planning for next position. First, separate each objective function to decide each one from its own perspective. Then, combine path planning for next position and so on. Thus, the next position of each robot is designed. Now the mobiles robots can move to the goal without collision [3]. Another approach deals with path planning based on grid map using modifications and improvements on A* algorithm. "The basic method assumption is a functional and reliable reactive navigation and SLAM" (Simultaneous Localization and Mapping) [5]. The scientific paper uses basic A* algorithm. Basic A* algorithm used for a grid configuration space, but this algorithm is not quite useful because there can be a lot of free space between the connected squares over long distances and these squares may not be linked next each other. Therefore, the searching in every angle is introduced. The algorithm uses searching in angles which called Theta* and Phi*. Basic Theta* and Phi* are modifications of A* algorithm. These modifications focus on chose the optimal path at least time. The article proposes that the algorithms are suitable in some cases while other algorithms are suitable in other cases [5]. Last approach we will talk about for autonomous mobile robot in un-known environment. The paper introduced singleton type fuzzy logic system controller and Fuzzy-WDO hybrid. The WDO (Wind Driven Optimization) algorithm is used to optimized and set the previous information and result

parameter of fuzzy controller. The proposed algorithms are successfully verified through simulations and real-time experiments in different environments [6].For this to achieve here I am using Dr robot (X80Pro is an upgraded version of X80, it has everything X80 has plus extras of 3 more sonar sensors (DUR5200), Tilting sensor,(DTA5102), Temperature sensor (DAT5280), IR remote control module (MIR5538), IR remote controller (DIR5538), the 128x64 mono graphic display (MGL5128) and two stronger (550oz-in, 40Kg.cm) motors).

2. PROBLEM STATEMENT

A* algorithm. A* is one of the best technique used in path finding field. We use A* as it's always find the optimal path in well-known environment. We introduce our environment for the multiple mobile robot system as static obstacles and another moving robot as dynamic as shown in figure 1. The proposed A* algorithm provide the optimal path between any two points in that environment.

Collision-Free. While two robots are moving to their goals it may cause some intersection on their path. The two robots are moving on grid map which is the map representation of the two robots. We solve this problem by preform a random function to give one of two robots the precedence of moving while the other robot is going to take a step back. After this step, the two robots going to continue to their goals by updating new paths. This is one of the challenges, different cases will be implemented on this problem.We introduce the environment for the multiple mobile robot systems as a static obstacle and another moving robot as dynamic as shown in figure 1.1

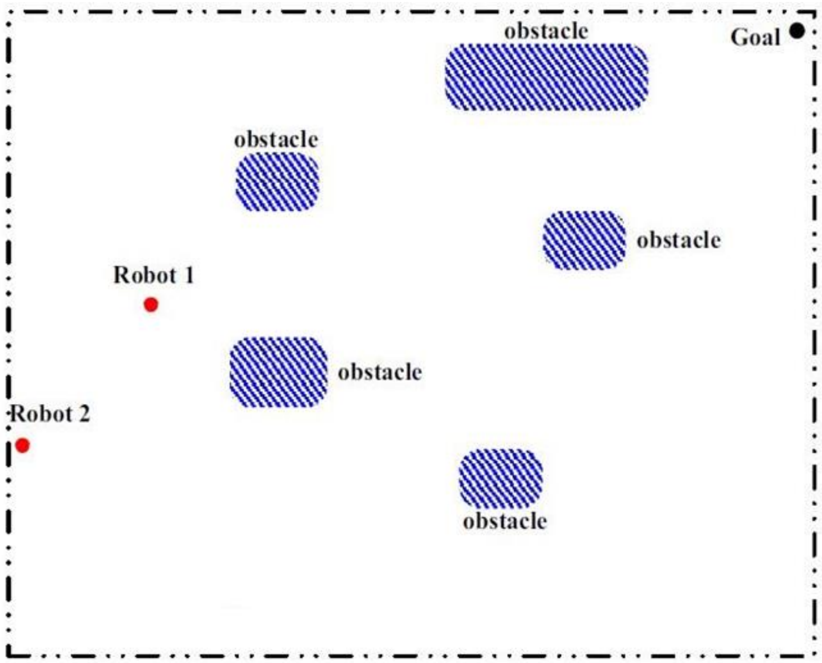

Fig. 1. Environment illustration of on-line path planning strategy for multiple mobile robots system.

3. AIMS AND OBJECTIVES

The aim is to make mobile robots system which plans optimal paths to move from their positions to the goal. The objectives are setup the environment using two robots and static obstacles. Design an algorithm to enable two robots to move from specific position to specific goal using A* algorithm while robots communicate with each other. Implement the algorithm in the real environment using robots of type Dr. Robot. A test sequence of operations in the real environment to evaluate the results.

4. BACKGROUND

In this chapter we introduce the field of path planning and why we need to solve this problem. We present different approaches from different scientific papers. We discuss one of the related work and see the different of what they use.

The concept of path planning related and have been used in many fields to solve different problems, in robotics path panning concern about finding a path from start to destination and with advancing in robot new challenges appear such as multiple robots and dynamic environments. In artificial intelligence path planning means the sequence of logical actions that the robot must follow to move from one point to another, a lot of decisions need to be taken in such a planning like in learning methods and information about the states [5]. However, recently many researches presented our problem which is path planning for multiple mobile robot system, the reason behind this is that multiple robots increase work capability and the performance. The main task in such planning is to guide a robot to the goal avoiding obstacles and other robots in the environment [3].

Another approach [5] deals with path planning based on grid map using modifications and improvements to A* algorithm. "The basic method assumption is a functional and reliable reactive navigation and SLAM" (Simultaneous Localization and Mapping).

The article used Basic A* algorithm. Basic A* algorithm used for a grid configuration space, but this algorithm is not quite useful because there can be a lot of free space between the connected squares over long distances and these squares may not be linked next to each other. Therefore, the searching in every angle is introduced. The algorithm uses searching in angles which called Theta* and Phi*. Basic Theta* and Phi* are modifications of A* algorithm. These modifications focus on choosing the optimal path at least time. The article proposed that the algorithms are suitable in some cases while other algorithms are suitable in other cases [5].

This paper [8] present methodology for path-planning in a known environment and static obstacles known as MBPP (Multi Bug Path Planning) it's close to bug algorithms family which kind of algorithms that use robot sensors to generate bugs when to reach some obstacle but instead MBPP use multiple bugs. In most global path planning A* algorithm used because of its optimality and simplicity but the path found by A* usually unrealistic because it's constrained to move along grid edges, so we need more smoothing techniques to deal with this issue. MBPP use the greedy move and generates a bug when reach obstacle, however, to avoid getting stuck in local optima MBPP generates new bug from the old one in both directions to move from greedy to non-greedy behavior when required. The bug that meets new states will continue to make greedy action until reach the goal but if it meets the previous state then it's terminated. MBPP use an online behavior in offline path panning so it's an algorithm that could be used for both deterministic and non-deterministic environments [8].

This paper [9] presents a new technique for line following and collision avoidance in un-known environment. This new technique relies on the use of low-cost infrared sensors and set of reenable of calculation, therefore, the robotic can be easily used in the real-time application. The technique setup implemented on multiple sensors of the robot to show the ability of the robot to do multiple tasks such as fallow a path, detect an obstacle and negate what around the robot to avoid obstacles. Also, the technique shows that the robot has been successfully following the path and avoid any obstacle. The simulation that used in this paper is Webots to validate the effeteness of the proposed technique. Finally, the research proposed that the approach can be easily used in different reel-time robotic application [9].

This paper [10] introduces improved path planning algorithm for multiple mobile robot systems for finding optimal path while robots interact with each other. This paper focus on finding the optimal path by doing less computation time using the re-planning algorithm. Each robot will upload information about location to MySQL server to plan safe distance between robots. Grid-based configuration usually used in path planning to find the optimal path by calculating the current cost and the cost to the goal, amount of computation depends on the size of a map. In online path planning grid cannot be used because the map will change while another robot moves. GA (Genetic Algorithms) used to find the optimal path but it's required a lot of computations. By using parallel processing, the experiment shows that the improved D* lite algorithm requires less computations time and give fast and more flexible paths for multiple robots [10].

Many algorithms and approaches have been represented to find optimal path for a mobile robot, however in many applications one or more objective considering in addition to the length of a path. This paper [11] focus on multi-objective path panning by considering Mars Rover in Mars-like environment scenario using A* algorithm which is simple, complete and optimal. The objectives considered in this article is to minimize the length of the path, the risk since there is a lot of obstacles like rocks and holes in Mars and minimize path elevation. The simulation results show that the algorithm is applicable in a real scenario [11].

Due to the physical complexity of the environment of robot working space, this paper [12] proposes a novel-multi-objective whale optimization algorithm (MWOA) in several criteria such as distance and smooth path. The algorithm which proposed by this paper based on Whale optimization algorithm (WOA). The environment is partially un-known of which is not surrounding by the robot and the obstacles are static. The target position and obstacles are considered the fitness for a path in WOA. The place of the global position best whale is selected in each iteration. The robot updates its information during its motion. The result in simulation shows that the proposed method effectively provides path planning task with good performance [12].

The aim of this paper [13] is to offer a comprehensive review of different approaches to mobile robots in dynamic environments and explains the advantages of reviewed paper. These articles were categorized based on the entire content of each paper into ten common challenges, the ten challenges are "traveling distance, traveling time, safety, motion control, smooth path, future prediction, stabilization, competence, precision, and low computation cost". according to the data gained from the environment, there are two types of motion planning which are global motion planning which is path planning under conditions based on known environment (off-line) and local motion planning which is path planning based on the local realized environment of sensors (on-line).There are many methods were presented in this article to solve the motion planning problem "Fuzzy Logic, Velocity Obstacles, Gap Vector, Fitting Circle, Collision Cone, Potential Fields, Follow the Gap, Directive Circle, A*, Neural Network, Biologically Inspired, Escaping Algorithm, Bayesian Occupancy Filter, Artificial Bee Colony, Ant Colony, Bacterial Foraging, Honey Bee Mating, Rolling Window, Q-Learning, Personal Space, Simulated Annealing, Sub goal-Guided Force Field, Vector Field Histogram, RRT*, Particle Swarm Optimization, Voronoi Diagrams, Genetic Algorithms and Generalized Complete Coverage were discussed"[13].

It is a path planning for mobile robot system in an unknown environment with dynamic obstacles [14]. Predict the next positions of moving obstacles by an autoregressive model (AR). A motion path in the dynamic unknown environment is planned with predicted positions, and it is based on polar coordinates in which the desirable direction angle is taken into consideration as an optimization index. Robot's sensor system detects positions of moving obstacles, then it is treated as instantaneously static. With these movements, the AR model predicts future obstacle's positions in the next sampling duration the robot should know obstacle information by its sensors in forward when moving in collision environment the robot avoid it by left or right directions then determine the next step [14].

There are many approaches applied to this topic as many types of research are conducted for. Path planning is an important issue for multiple mobile robot system approaches, epically on-line path planning approach [3]. One of the uses of the solution on this filed is maintenance automation. The robot system must plan autonomously the different manipulation tasks and the corresponding paths [15]. Another use of path planning are for Vehicles. The optimal path planning problem for the vehicle navigated by a technology called NRMS (The navigation relayed by multiple stations). NRMS is an advanced navigation technology which relies on multiple stations to guide a vehicle to its destination [16]. Different approaches mentioned previously try to solve path planning problem.

Let's take one of them and talk about. One of the paper uses efficient artificial bee colony (EABC) algorithm. The environment is known. "The proposed EABC algorithm enhances the performance by using best individuals for preserving good evolution, the solution provides a proper direction for searching, and the update strategy provides the newest information of solution". Each situation design path planning for next position. First, separate each objective function to decide each one from its own perspective. Then, combine path planning for next position and so on. Thus, the next position of each robot is designed. Now the mobiles robots can move to the goal without collision [3]. The paper uses a similar approach when considering the unknown environment, the obstacles are static, and another robot is dynamic. Lots of scientific paper consider the environment either static or dynamic as shown in next table.

Table 1 Environment Comparison

No. of reference	Dynamic environment	Static environment
My Proposed Work	✓	✓
[3]	✓	✓
[5]	✓	
[8]		✓
[9]	✓	✓
[10]	✓	
[11]		✓
[12]		✓
[13]	✓	

For My work, I use the middle approach partially between static and dynamic on the environment. I use a simple algorithm to find the optimal path considering re-plane the path in some cases. I represent the map as squares have fixed length and diagonal. Of course, the diagonal edges have a different measurement. For rotating the wheels of the robot, we consider the time on second of the degree of routing the weal to direct the robot to the correct position. We like others use grid-map occupancy the approaches it stands for how the robot represents the map and move through it.

On this chapter, we mentioned the field of path planning. I bring some solution used currently to solve the problem. I discuss one of similar work the general method they use. I mentioned the similarity and difference so far.

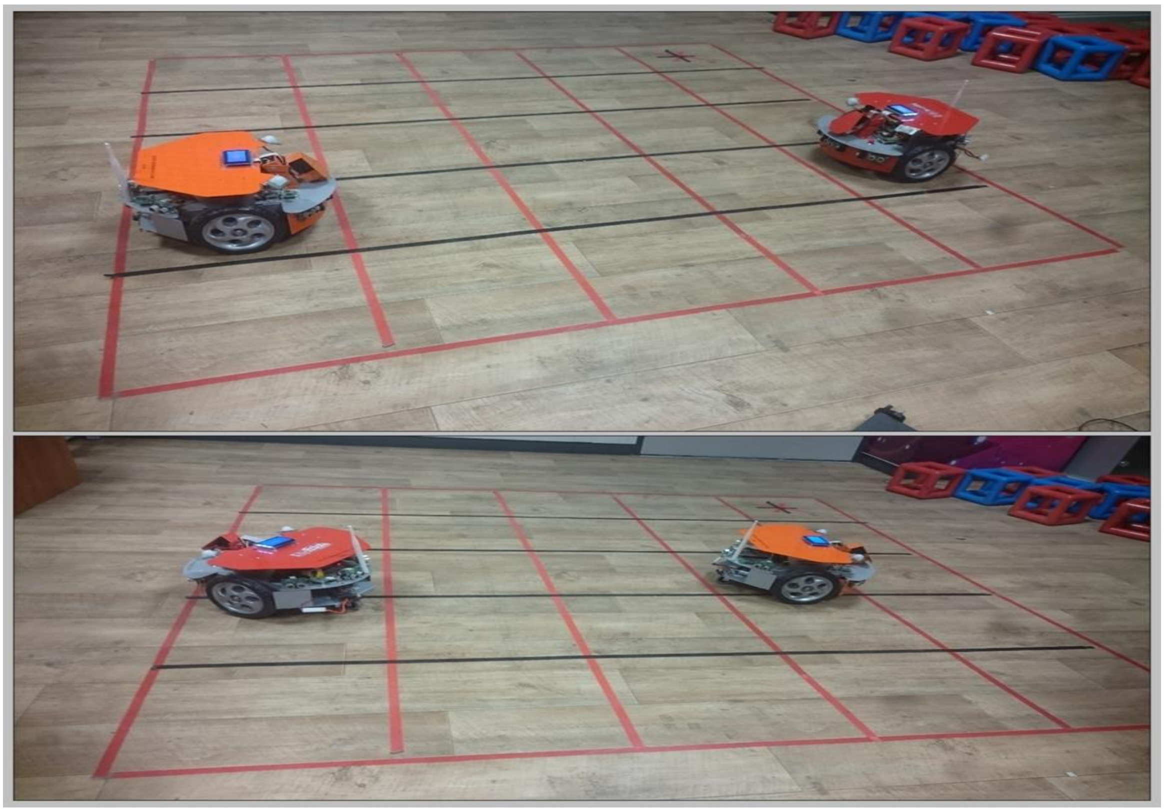

Fig.2 Here is the sample image of robots used

5. ANALYSIS

In this section I introduce a basic scenario that can be used by the user to run and test the algorithm in a real environment:

1- My example consists of two robots of Dr. Robot type (X80 pro Model) in the grid-based static environment.
2- Connect to the robot using the computer.
3- Open windows application to control the robot.
4- Enter search parameters (map size, start point, goal point ...etc.)
5- Program will generate the path as a sequence of action to the robot to move based on it from start to goal.
6- By using sensors on two robots they can detect obstacles and another robot.
7- If robot detects new obstacles in the environment then it will update the map with a new obstacle and generate another path from the current position to the goal.
8- The two robots should enable to reach their goal position from initial one with free-collision with obstacles and with optimal path.

5.1. Functional requirements

- Control robot's movement
- Use robot's sensors for detecting obstacles
- Create an optimal path from start to goal position in the environment
- Use the sensors information to decide new decisions
- Update the path in some cases

5.2. Non-Functional requirements

- Using the Dr. Robot moving functions
- Using Sonar Ultra-sonic sensors to detect obstacles
- The optimal path is calculated by A* algorithm
- Using grid map representation, and the environment is known
- The measurement of robot's movements should be accurate

6. METHODOLOGY

At first, I introduce our environment for path planning of multiple mobile robot's systems as a grid map consists of square points of equal size and every square represents one move of the robot, each robot has initial position and go through the map avoiding obstacles and the other robot to reach the goal position using Adjusted A* Algorithm and re-planning path.

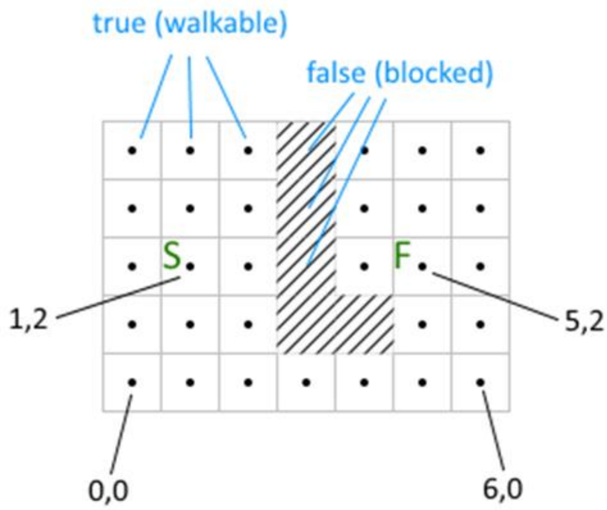

Figure 3 Initial Representation of the Map

A* algorithm is one of the artificial intelligence techniques used for path finding, A* always find the optimal path in static well-known environment as our environment in this project, using objective function (F) that is calculated as: F = G + H, where G is the cost of the current position and H is heuristic function that estimate the cost to the goal position. At each step the next position (Xn , Yn) is determined from the walkable adjacent locations of the current that has the lowest cost (F) and while checking if there is no conflict with the other robot in the next step and re-plan the path if there is intersection with other robot to find a sequence of points which represents the path to the goal position.

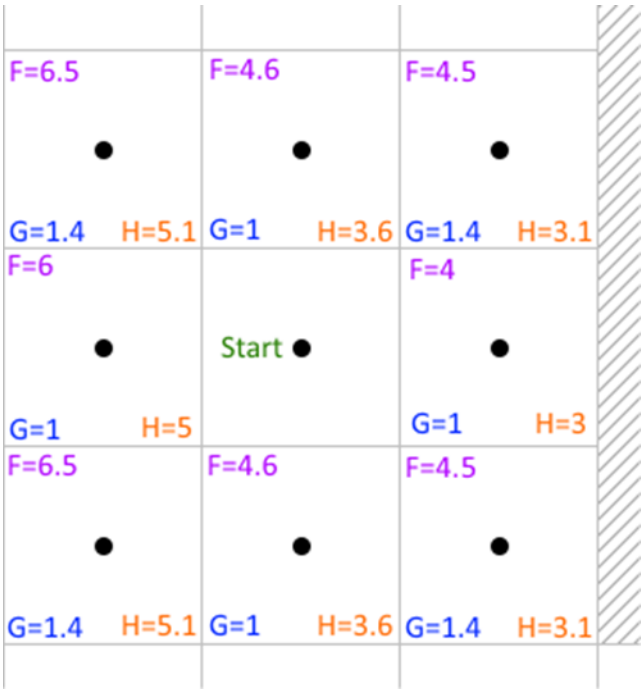

Figure 4 calculate Fx for each adjacent location

Free-collision path planning with global search and local optimization:

Path planning in the well-known environment and static obstacles global search algorithms are usually used but since there are multiple robots in the environment, so we do a local optimization at each step of the robot movement through the path to the goal.

When the robot start from initial position in the grid map that consists of squares of equal size that will also contain information about obstacles and the goal position, the robot will have 8 locations in the next available locations to go through it either directly or diagonally, using A* algorithm the robot will always choose the next location that has the lowest cost (F) which is G + H, G is the cost of the current location which is calculated as Gx-1 + G(x-1,x) where Gx-1 is the cost of parent node and G(x-1,x) is travel cost from parent to current node, H is a heuristic function which is Euclidean distance from current node to the goal, In mathematics, the Euclidean distance is straight-line distance between two points in Euclidean space and it's calculated as √(〖(x_n- x_i)〗 ^2∓ 〖(y_n- y_i)〗 ^2), where (x_n . 〖 y〗 _n) is the goal location and (x_(i). 〖 y〗 _i) is the current location, we use Euclidean distance because it's admissible heuristic that's mean it never overestimating the distance to goal position. Location that has obstacle or has been searched before and added to the path or not in the grid map boundaries will not be considered in the next available location, also diagonal movements of the robot for the next location will depend on the obstacles near the current node as the robot cannot go diagonally if it will be through location that has an obstacle to avoid colliding with the obstacle.

The previous method gives us best selection of the next location; however, we still have another robot moving in the environment and we consider it as the only dynamic obstacle there. Here we use the optimization function for each step to check if there is a new obstacle which will defiantly be the other robot, checking will be done after directing the robot to be ready for moving to next square, this case will guarantee that the robot will not consider any other obstacle instead of the obstacle on the next square if found. We activate only one middle front sensor, which let the robot detect the obstacle that on the next square and ignore all obstacles in other sides. This case will guarantee free collision to every step is done by robot by detecting the obstacle before moving. There is a case we couldn't handle it by this way of detecting which if the two robots at the same time chick the square then move together to the same square, they will collide to each other. So, we apply another way which is activating all sensors while interring the square then if detect any other robot interring the square it will stop then get the priority by randomness, so less priority will step back, and re-plan other way and high priority will wait 2 seconds for giving the other robot the chance of getting a way then complete its way and if all of them got the high priority they will get another priority by randomness until one of the get the less priority.

7. CONCLUSION

Here I am giving some approaches and methods used in path planning field and the method I choose and implement.

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