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Path Planning with Static and Dynamic Obstacles Avoidance Using Image Processing

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Abstract

Robotic navigation is an important apprehension for an autonomous project, and for robots with specialized modes of movement, it can be especially difficult to conduct path planning. In this work, the authors evaluate a path planning model by analyzing the environment based on an image processing method. The main target of our work, build the environment of a robot with static and dynamic obstacles, for static obstacles the authors suggest the environment as an image by using MATLAB software and find the shortest path between any two points in the space with obstacles detection and avoidance using A* algorithm using Euclidean distance to compute the heuristic distance of the start point to the destination, then determining the number of steps(pixels) from the source point to the destination and compute the time required to reach the goal.

Disciplinary: Electrical Engineering (Robotics & Image Processing).

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1 Introduction

In many fields, such as robotics, artificial intelligence, or control theory, the principle of path planning has been developed. That is why each researcher makes use of this term's own meaning. Route planning apprehensions in robotics with problems such as how to move a robot from one point to another. There are also several problems such as uncertainties, multiple robots, and dynamic obstacles with the advances of path planning [1]. Forward kinematics and, later, inverse kinematics is necessary for the design of any work in robotics systems[2].In this work Forward kinematics was considered. The path planning method defines in this paper goals to calculate the shortest path for robots while avoiding obstacles along the way. Robotics Path planning is a complex task. To find the optimal path in the environment between the starting point and the target point. A map is typically needed to find and follow the shortest path[3]. Only one robot is permitted to enter the assembly area at a time to entirely exclude the potential of a collision [4]. To measure the path more efficiently, the method of path planning discussed in this paper is based on image processing. The shortest path is obtained by the A* (A-star) algorithm. The A* algorithm is used for mobile robot navigation [3]. As a grid, it assumes the whole workplace. The path that covers the smallest number of grid cells to meet the target is calculated by the algorithm. The heuristic function is used by the A* algorithm and its value is determined at each node in the workspace to get the optimal solution [3]. In robotics, route planning typically focuses on developing an algorithm to produce useful movement with optimal different paths there is free space and space filled by the obstacles in the area in which the robot travels as shown in Figure 1. In free space, the beginning and objective arrangement are located. The dynamic environment is the environment that comprises shifting barriers, while the static environment does not alter over time [5].

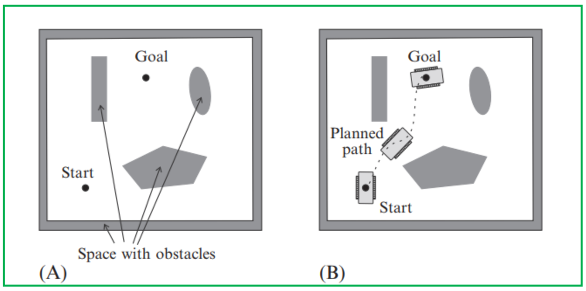

Figure 1: (A)Environment with barriers and configurations of start and goal, and(B) One setting from the beginning to the target configuration, from possible paths.

2 Image Processing

The development of image processing and computer vision techniques is increasingly present to ensure the control and automation of processes [6]. To delete features that do not require robot path generation, the image taken should be treated [7].

The first step in a series of algorithms is to classify obstacles in the picture taken. In this article, all pictures are processed as gray-scale images. Since the amount of information can be reduced to one-third of color images, and the color is unlikely to be relevant in the planetary climate[8].In this research to detect the obstacles the following steps needed are:

1. The image is transformed from RGB to a grayscale image. This conversion will reduce the quality of the image's details and helps to better process it, we suggest black color as obstacles and white color as free space.

2. The gray image is converted into binary coding, where the obstacles are represented by binary 1, and the free space is represented by binary 0.

Visual information processing technology relies primarily on the method of image processing in the robotics vision system, including image transformation, image compression, coding, and so on [9]. Where the robust system of vision should detect objects providing an accurate and reliable representation of the world for processing by the higher-level processes. The vision system must necessarily be extremely successful, enabling a resource, constrained agent to react rapidly and promptly to a changing situation of the environment [10].

3 A* (A star) Algorithm

A* (A-star) is an insightful algorithm because it contains additional or heuristic data. the heuristic is the cost estimate of the route from the current node to the destination[5]. This algorithm is a path-finding algorithm, an extension of the algorithm of Dijkstra. which, by using heuristics, achieves better output (in terms of timing) in comparison to Dijkstra's. Each cell in the grid is evaluated according to an evaluation function given in Equation 1 during the search process for the shortest path[11]. where the algorithm calculates the heuristic function for each node which is the cost estimate for the path from the current node to the objective (cost-to-goal) are named. Euclidean Distance or Manhattan Distance may be the heuristic feature(sum of vertical and horizontal moves). The cost of the entire path (cost-of-the-whole-path) is determined for each node during execution to consist of cost-to-here and cost-to-goal [5]. The A* algorithm uses heuristic search and search combinations based on the shortest path, where it is known as the best-first algorithm because the value is calculated for each cell in the configuration space as [1]

$$f(v) = h(v) + g(v) \quad (1),$$

where $h(v)$ is the cell's heuristic distance (Manhattan Euclidean) to the target point, and $g(v)$ is the distance traveled by the robot through the selected cell sequence from the starting location to the destination. This sequence obviously ends in the cell that is actually assessed. The value $f(v)$ is evaluated for each adjacent cell of the cell actually assessed. the cell with lowest $f(v)$ is chosen to be the next one The benefit of this algorithm is that it is possible to presume, change or add other distances to the distances used as a condition. This gives this universal idea a wide variety of modifications. Time, energy consumption, or protection, for example, may also be included in function $f(v)$, as a robot route planning algorithm [1]. Algorithm A* is an algorithm that is compact and efficient and it is a standard artificial intelligence heuristic search algorithm as compared to the other artificial intelligence algorithms. It has many other benefits such as artificial intelligence algorithm, running time, high productivity, quick implementation[12].

4 Scenarios

It can be present two scenarios for this work as below.

4.1 For an Environment with Static Obstacles

The main work is as follows: first, build the 2D environment of mobile robot with static obstacles, we suggest the environment as an image by using MATLAB software. Second, analysis the environment by using (image processing), Including image loading, image conversion from RGB to gray, and then converts to binary coding, so that the environment can be described as a set of obstacles and free space where the obstacles are represented by binary(1) and the free space represents by binary zero(0). third, the program finds the shortest path between any two points in the space with obstacles detection and avoidance using the A* (A-star) algorithm which applies Euclidean distance to compute the cell's heuristic distance (Euclidean) to the target state and the path length from the initial position to the target point as

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (2).$$

Finally, the program computes the number of steps (pixels) that perform the path. Then find the number of steps by determining the number of pixels from the starting point to the target. then, the code computes the time required to reach the goal.

4.2 For an Environment with Dynamic Obstacles

In this research, the design of a 2D environment with (x*y) is implemented, where the values of x and y are selected to be 200 pixels. Our environment consists of three dynamic obstacles as a circle in shape. Therefore, it is defined the circle as (x,y,r), where the x is the horizontal axis, y is the vertical axis and r is the radius of it. These circles move from right to left and vice versa. The path between two points can be found in this environment with obstacle detection and avoidance, the robot check all directions to move from one place to another, such as right, up-right, down-right, up, down, down left, up left, and left. Then select the shortest path between them by using the Euclidean distance equation. Finally, the program determines the time required to travel from the start point to the endpoint and computes the number of steps from the start point to the goal point.

5 Implementation

The mobile robot route can be checked between any two points in the environment with different cases.

5.1 An Environment with Stationary Obstacles

When running the code, it can get the path between any two-point as in the following cases, where the time is also computed in the code which is required to travel from the source point to destination as in Table 1.

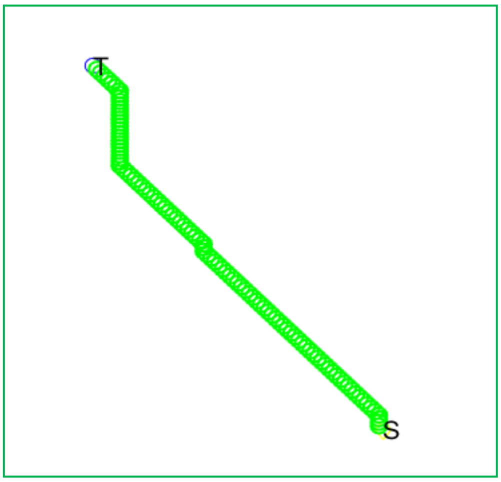

Figure 2: Free obstacles environment.

Case 1

An obstacle is there where the robot is starting from point (24,22) to (100,124) as shown in Figure 2.

Case 2

The obstacles have been added to the environment with different start and endpoints as presented in Figures 3,4,5,6.

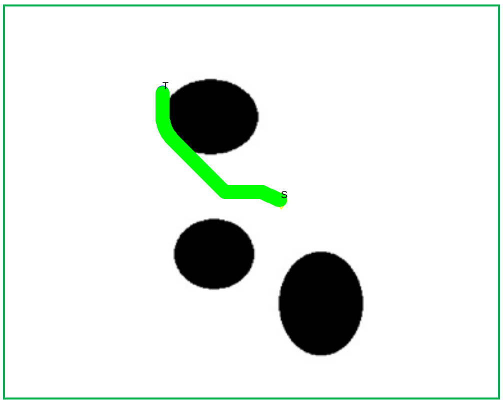

Figure 3: Path planning with obstacles from point (50,50) to point (170,160).

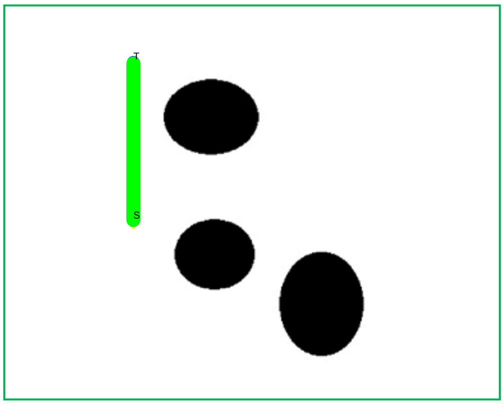

Figure 4: Path planning with obstacles from point (20,20) to endpoint (20,180).

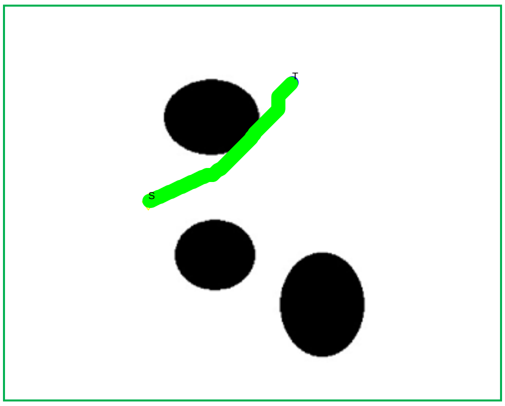

Figure 5: Path planning with static obstacles from point (180,40) to point (35,160)

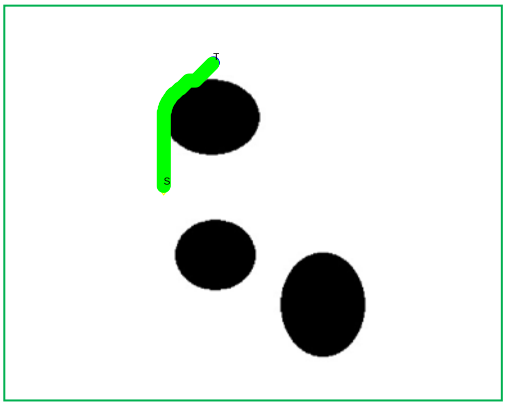

Figure 6: Path planning with obstacles with start point (100,20) & target (50,145).

Table 1: Results for static obstacles environment

Case No.	Start point	Target point	No. of steps(pixels)	process Time(minute)
1	(50,50)	(170,160)	159	16.14
2	(20,20)	(20,180)	161	8.63
3	(180,40)	(35,160)	161	23.01
4	(100,20)	(50,145)	135	13.02

5.2 An Environment with Dynamic Obstacles

Circular dynamic obstacles have been utilized in this test where different scenes are given in Figures 7, 8, 9, 10. Time process and path length(number of steps in pixel) can be described in Table 2.

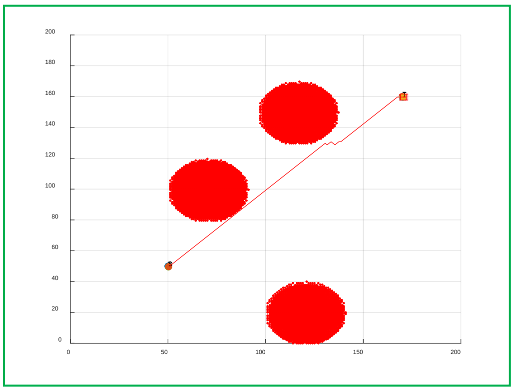

Figure :7 Path planning with dynamic obstacles from (50,50) to (170,160)

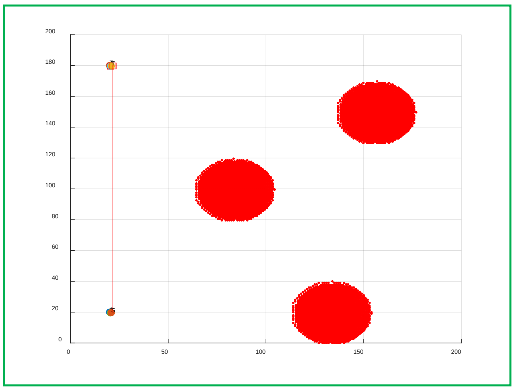

Figure 8: Path planning with dynamic obstacles from (20,20) to (20,180).

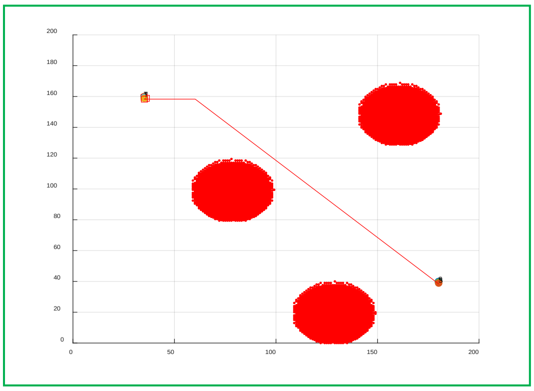

Figure 9: Path planning with dynamic obstacles from the start point (180,40) to target (35,160).

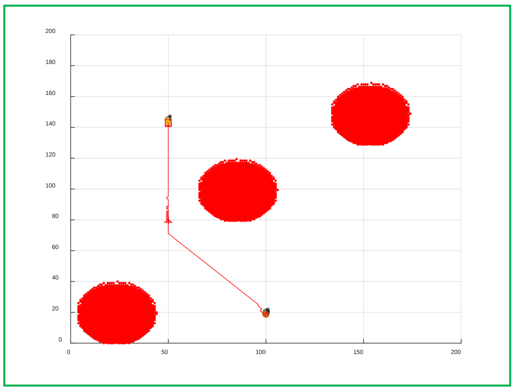

Figure 10: Path planning with dynamic obstacles from (100,20) to (50,145).

Table 2: Results for dynamic obstacles environment

Case No.	Start point	Target point	No. of steps(pixels)	process Time(second)
1	(50,50)	(170,160)	124	51.166
2	(20,20)	(20,180)	163	62.03
3	(180,40)	(35,160)	148	62.04
4	(100,20)	(50,145)	169	64.76

6 Conclusion

A path planning and motion planning system for autonomous robots based on image processing seems to be an excellent tool for robotics vision. Since image processing determines the position of obstacles, the shortest path to the destination. By integrating two fundamentals of image processing, the obstacle detection method image conversion, and image coding by searching dark and bright pixels where the dark pixels are represented by logic 1 but the bright pixels are represented by logic 0.

7 Availability of Data and Material

All information is included in this study.

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