Subgoal Generation Algorithm for Effective Composition of Path-Planning

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Abstract: In this paper, we deal with a novel path planning algorithm to find collision-free path for a moving robot to find an appropriate path from initial position to goal position. The robot should make progress by avoiding obstacles located at unknown position. Such problem is called the path planning. We propose so called the subgoal generation algorithm to find an effective collision-free path. The generation and selection of the subgoal are the key point of this algorithm. Several subgoals, if necessary, are generated by analyzing the map information. The subgoal is the candidate for the final path to be pass through. Then selection algorithm is executed to choose appropriate subgoal to construct a correct path. Deep and through explanations are given for the proposed algorithm. Simulation example is given to show the effectiveness of the proposed algorithm.

Keywords: Subgoal generation, Map-based, Path-Planning, Robot navigation

1. INTRODUCTION

The navigation problem of mobile robot in obstacle environments while avoiding collisions with obstacles is known as obstacle avoidance or path planning. The obstacle avoidance problem is one of the fundamental topics for mobile robot research area. The goal of collision-free path planning is to find a continuous path of a robot from starting position to goal position, while avoiding collision with the obstacles.

Researchers have proposed and developed a variety of path planning algorithms: A* algorithm[2,3], D* algorithm[7] and fuzzy system[8,9] etc. The basic difficulty of the existing path planning algorithms is that they are computationally intractable. Many researchers have endeavored to find effective path planning algorithms in obstacle environments.

In this paper, we present a novel type of path-planning algorithm for finding effective collision-free path in a complex environment. The generation and selection of subgoal are the key point of this algorithm. The subgoal is a bridge to guide the robot to the target position in a complex environment. For establishing an effective path to the goal, we analyze the map which contains the information of collision free paths and the obstacle position[1,5]. Suitable subgoals are generated based on the extracted map information.

If the robot encounters with an obstacle in a checking area, the proposed algorithm will create two subgoals. In selecting the subgoal to construct an effective path planning, the subgoal cost is evaluated by calculating distance[1]. This paper proposes a selection algorithm to determine an appropriate subgoal based on the cost analysis of connection relationship between 3 points: initial, target and subgoal points.

2. PATH-PLANNING ALGORITHM

A new path planning algorithm is proposed to accomplish effective navigation of robot. The algorithm is based on the searching of subgoal. The subgoal is a passing point to guarantee a collision-free path for avoiding obstacles. The key point of this algorithm is the generation and selection of the subgoals.

2.1 Subgoal Generation

We check whether there exists obstacle between two points area from starting point to target point by using of the search line. The search line is a straight line between two points. If an obstacle exists on the search line, the proposed path planning algorithm is executed to construct subgoal. The subgoal is created by analyzing gathered information about obstacle of arbitrary form and the robot characteristics itself.

Fig. 1 represents the subgoal generation in a simple environment contains only one obstacle. When the search line finds the obstacle, the proposed algorithm establishes the new two points of intersection: beginning point and finishing point. And then we draw the vertical line at the middle point between this two points. The vertical line forms the basis to determine the position of subgoals.

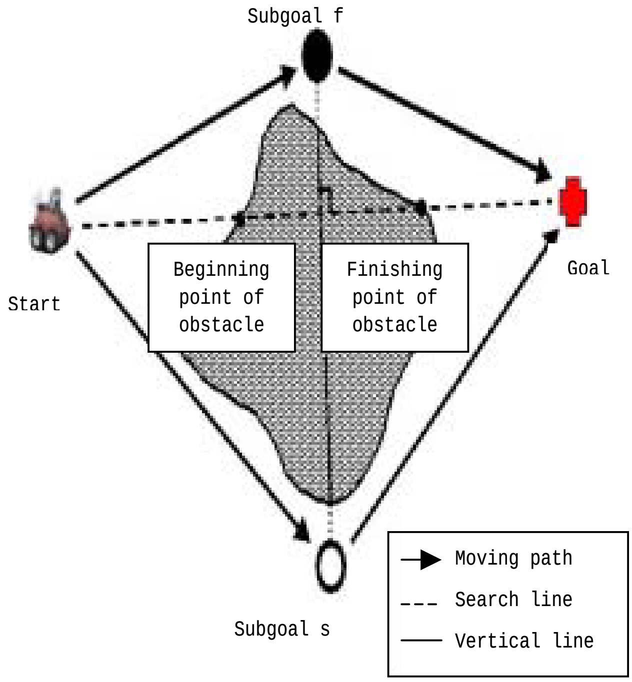


Fig. 1 Subgoal generation

The subgoal selection algorithm is explained in section 2.2 to find a better effective subgoal f in Fig. 1. This subgoal has less distance cost than that of another subgoal s.

2.2 Subgoal Selection

The subgoal selection algorithm is derived on the basis of the sum of two distances: the distances from initial point to subgoal and from subgoal to target point. Then the subgoal costs are expressed as the following.

$$\begin{aligned} Subgoal1\ Cost &= d_1 + d_2 \\ Subgoal2\ Cost &= d_3 + d_4 \end{aligned} \quad (1)$$

Fig. 2 illustrates the relation between rotation angle and distance at subgoals. From this figure, we can see that the subgoal 1 could be selected as the appropriate point to get a shorter distance from virtual start to virtual target. Also, we can observe that rotation angle of a robot at the subgoal 1 is less than at the subgoal 2.

The word 'virtual' is used to clarify that it is not the actual starting or target point. If an obstacle is found between two subgoals to be connected, the proposed algorithm will create new subgoal between the previous subgoals. Then we set up one subgoal as a virtual start and another subgoal as a virtual target.

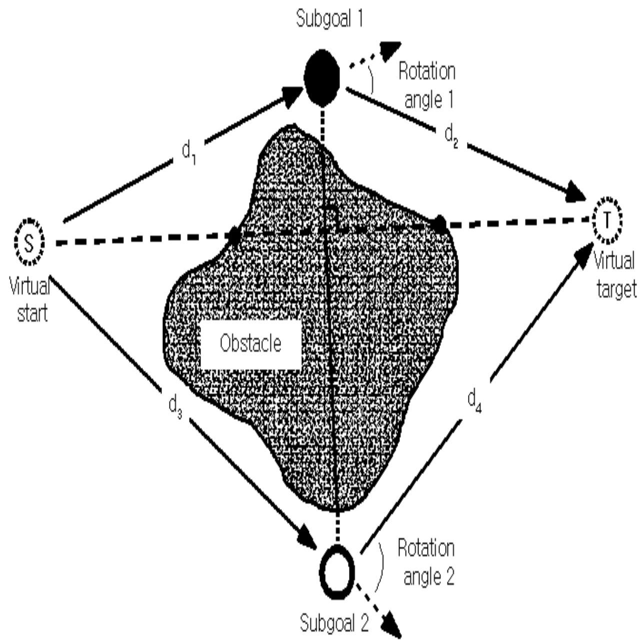
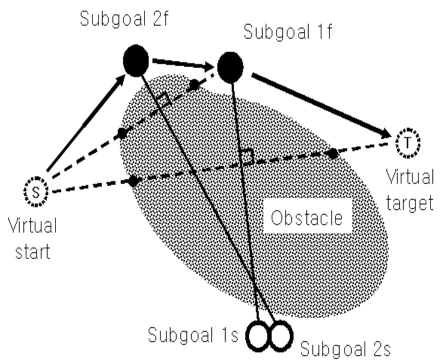


Fig. 2 Relation between rotation angle and distance at subgoal

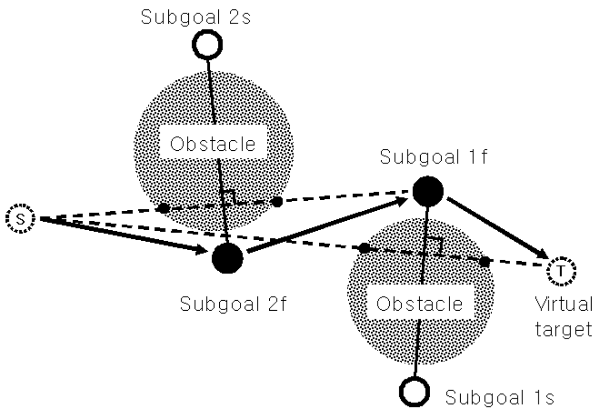
2.3 Subgoal Connection

For avoiding arbitrarily shaped obstacle, the algorithm creates and connects many subgoal points in order to give satisfactory path from the starting point to the goal point. To establish a collision-free path in a complex environment, two occasions are happened when we connect the generated many subgoals.

First case is when the robot perceives obstacles between the start and subgoal point. In this case another subgoal is needed to escape the obstacle. To create a new subgoal, start and finish points are required. This is resolved by regarding the subgoal point as a virtual target point. Then the bypass can be constructed by connecting the start point, new subgoal point and pre-subgoal point in order.



(a) Complex obstacle

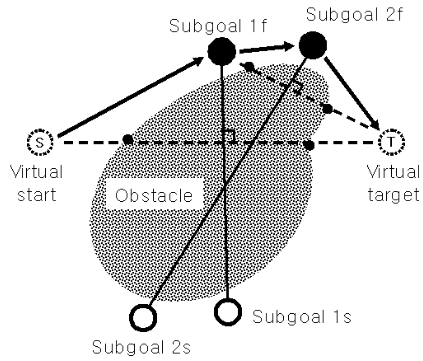


(b) Multiple obstacles

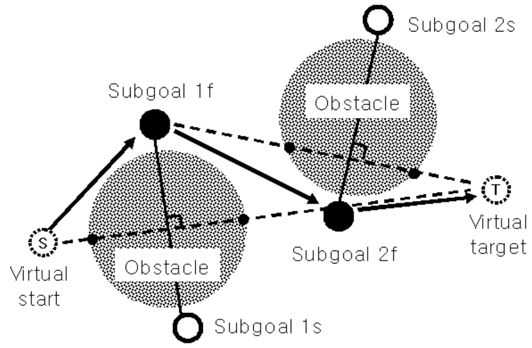
Fig. 3 Case where subgoal is not connected to virtual start

Second case is when the robot perceives obstacle between the subgoal point and the target point. Similarly to the preceding case, another subgoal is created to detour an obstacle. The new subgoal is generated by regarding the previous subgoal point as a new starting point. Then the resulting path is constructed by connecting the subgoal, new subgoal and target point in order.

Fig. 3 represents the first case where subgoal is not connected to virtual start. The subgoal number is in creating subgoal order. Fig. 4 represents the second case where subgoal is not connected to virtual target directly.



(a) Complex obstacle



(b) Multiple obstacles

Fig. 4 Case where subgoal is not connected to virtual target

3. Simulation Results

Simulation examples are provided to compare the proposed subgoal generation algorithm with the A* algorithm which is known as a general path-planning algorithm. The simulation runs in virtual environment that consists in squares 10x9 blocks.

Fig. 5 shows that there is little difference between the two algorithms in view of the resulting collision-free path. Therefore the proposed algorithm could be regarded as an alternative method to compose effective path-planning.

In the process of the proposed algorithm sequence, the subgoals are created successively to reach the target position without colliding with obstacles. But the exploration area owing to the proposed algorithm is much smaller than that with the A* algorithm for a given environment. Nevertheless, two algorithms give the similar results to draw an effective path.

The table 1 shows that the proposed algorithm has little path block for moving robot from start position to target position than the A* algorithm.

Table 1. Moving path

	Connection moving path
The proposed algorithm	(9,0)->(7,0)->(6,0)->(6,1)->(5,4)->(5,6)->(4,7)->(3,7)->(0,8)
A* algorithm	(9,0)->(8,0)->(7,0)->(6,1)->(5,2)->(5,3)->(5,4)->(4,5)->(3,5)->(2,5)->(1,6)->(0,7)->(0,8)

4. Conclusion

In this paper, we introduce the generation and selection subgoal algorithm to accomplish effective path-planning. The generated subgoals are connected systematically to compose an effective path in the complex environment. The simulation result is given to show the effectiveness of the proposed subgoal generation algorithm.

Future work will be focused on the extension of the subgoal algorithm for a 3-dimensional environment.

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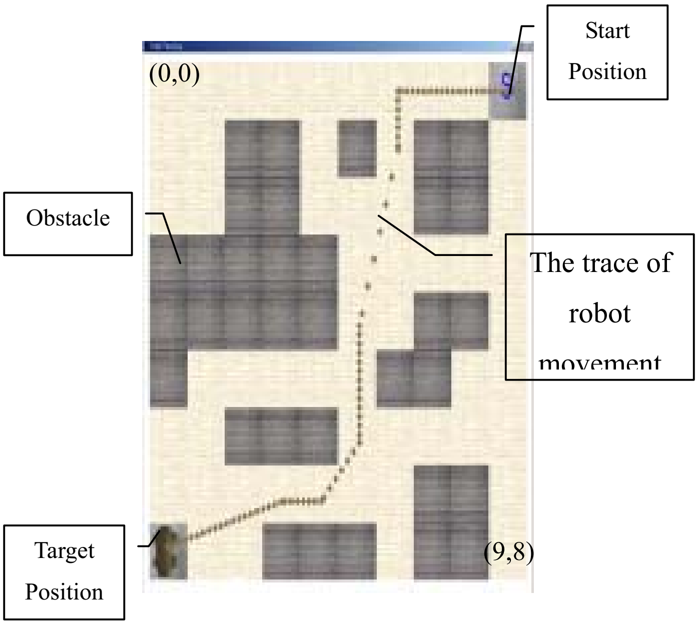
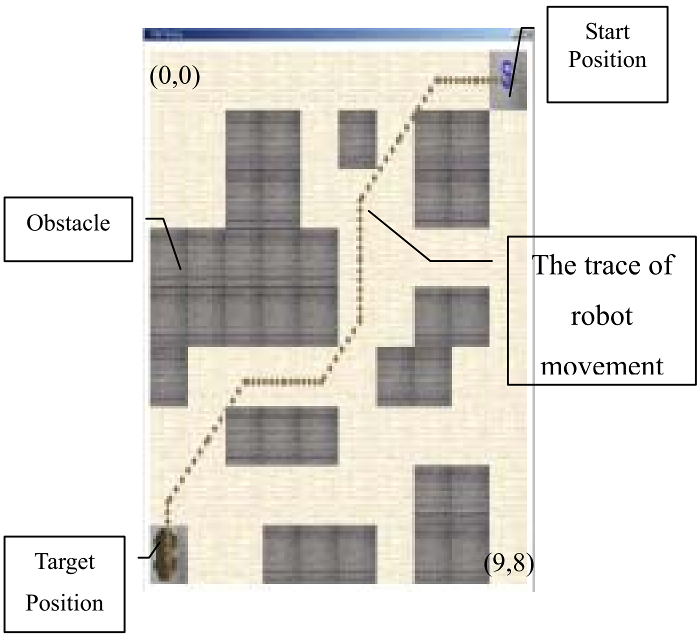


(a) In case with the proposed algorithm



(b) In case with the A* algorithm

Fig. 5 Path comparison between two algorithms