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Automatic Construction Method of Topological Map of Obstacles in Mining Area

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Abstract:

Constructing obstacle map is a necessary step before unmanned driving system carries out path planning. Aiming at the application of autonomous driving in mining area, the author proposed a fast method of constructing obstacle topological map, providing route planning map information for autonomous vehicles. Considering the practical problems of obstacles in mining scenes, such as goods, vehicles and people, change frequently, this paper first constructs a prior map, then fuses the obstacle map in real-time positioning, and constructs a topological map based on the fused map for path planning.

Keywords*: Obstacle map, Automatic obstacle avoidance, Unmanned driving, Autonomous navigation.*

I. INTRODUCTION

In recent years, unmanned mobile platforms are widely used in various scenes, such as industrial scenes, unmanned storage, smart homes, hotel meals, etc. Unmanned mobile platforms can automatically plan paths and avoid obstacles, and realize roaming tasks in scenes. The important premise to complete the task of automatic route planning and obstacle avoidance is to construct the topological map in the scene and form the expression of the road network in the scene.

The establishment of topological map is usually completed in two steps: obstacle map acquisition [1,2] and topological map generation [3,4]. Map acquisition is to mark obstacles and feasible areas in the scene through sensor data. Sensors can use vision, laser and millimeter wave radar and mark the corresponding points in the scene as obstacles or feasible areas by acquiring the geometric or semantic meanings of the data. Map generation methods are mostly based on topology segmentation, including morphology, distance transformation, Vino graph and spectral clustering. However, when using the constructed topological map for path planning, due to the dynamic changes of the scene, it is also necessary to consider the obstacle distribution of the instantaneous scene.

Aiming at the application of automatic driving in mining areas, and considering the practical problem that obstacles in the scene, such as goods, vehicles and people, change frequently, the author put forward a method of quickly constructing and updating obstacle topological map, providing map information of path planning for self-driving vehicles.

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II. SYSTEM FRAMEWORK

The framework of the method proposed in this paper is shown in Figure 1. The system uses the point cloud data obtained by laser radar sensor as the input. The point cloud data first forms a prior map. The purpose of the prior map is to construct the road prior of the global scene road network and form complete road information, which is further rasterized to form a raster map. When running in real time, the radar point cloud data will form an obstacle grid map in the current visual angle. After fusing with the prior road network map, an obstacle fusion map will be generated. Based on this map, a road network topology map will be constructed to serve the path planning task.

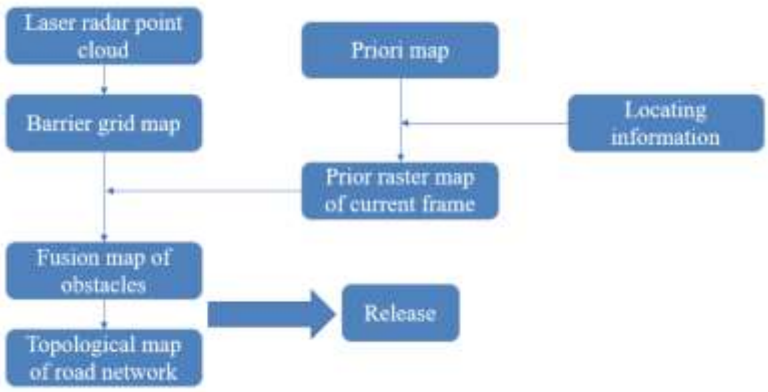

Fig 1: System framework for automatic construction of obstacle topological map

III. PRIOR MAP CONSTRUCTION

In this paper, the input of prior map construction is laser point cloud data and inertial navigation sensor data, and the open-source Cartographer framework is adopted [6]. Given the raster map and the point cloud information obtained by the current laser sensor, the basic idea of mapping is to project the point cloud data onto the raster map and find a pose to minimize the re-projection error of the laser point cloud. Cartographer is used to construct scenes by creating subgraphs. However, as the number of subgraphs increases, there is a problem of rapid error accumulation. To eliminate and reduce errors, closed-loop detection is usually used to optimize the pose of all subgraphs.

Cartographer's closed-loop detection uses correlation scanning matching method. That is, when new data is obtained, the best matching frame is searched in a certain range around it. If the matching frame meets a certain threshold, it is considered that the closed loop is detected. However, when the search window is too large or the search step size is too small, the search process will take a lot of time. In order to improve the efficiency, Cartographer chooses to search by branch-and-bound method. It is a search method put forward by Charles Karp, which successfully solves the traveling salesman problem [7] involving 65 cities. Its main idea is to divide the solution space into small subsets (branches) and calculate a lower bound or upper bound (bound) for each subset. Aft each branching, those subsets whose boundary

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exceed that known feasible solution value are not further branched. In this way, many subsets can be ignored, thus narrowing the search scope.

Specifically, the pre-calculation grid is introduced into cartographer. First, the original resolution map is introduced, which is the map with the highest resolution. The pre-processing stack stores N raster maps with different resolutions. At the bottom of the stack, the original resolution map is stored; at the top, the maps compressed by 2, 4, 8 and 16 times are stored; at the top of the stack, the maps with the lowest resolution are stored.

Maps of different layers are matched in maps with different resolutions for subsequent correlation matching, that is, layers in branch-bound method. To ensure the correctness of the upper boundary, that is, the score in the top layer being higher than that of the bottom node, the compressed map is not sampled from the original map at a fixed interval, but the maximum probability values of all coordinates in the fixed interval are taken as a low-resolution map. The preprocessing of the whole map stack is completed by analogy at one time.

As shown in Figure 2, (a) is the input point cloud data, and the color route is the movement track of the sensor in the visual map constructing. After closed-loop detection, a closed route track is formed. On the basis of route (a), the trajectory is expanded by morphological method, as an approximation of prior road network, as shown in figure (b).

(a) Point cloud input and closed-loop detection (b) Expanded road network

Fig 2: Prior map construction

IV. CONSTRUCTION OF BARRIER GRID MAP

In the process of positioning, to deal with the problem of dynamic scene changes, this paper constructs the obstacle map in real time and expresses it as a grid map. That is, the map is discretized and expressed as a grid, and the data in each grid represents the obstacle with 1 and the feasible area with 0.

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First, as shown in Figure 3, the plane is divided into a plurality of grids on average. If a grid contains a plurality of point cloud data larger than a certain height difference threshold compared with the ground, the grid is an obstacle, and the grid is written as 1, otherwise it is written as 0. After traversing all grids, an obstacle grid map can be generated.

(a) Original input (b) Raster map

Fig 3: Raster map representation

V. CONSTRUCTION OF ROAD NETWORK TOPOLOGY MAP

After obtaining the prior map and the current positioning information of the sensor, the prior obstacle information around the sensor can be extracted from the regional prior map, and then the prior obstacle information and the obstacle grid map of the current frame can be fused to generate a more accurate obstacle topology map, which will be used for path planning.

Figure 4 shows the fusion result of prior map and current obstacle map, in which the red area is prior map, and each red point is the feature point extracted in the process of constructing prior map; the white point is the obstacle point obtained at the current position, and the fusion result of the two points will be used as the input of obstacle topology map generation.

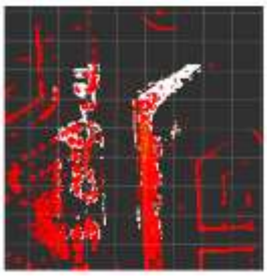

Fig 4: Map fusion

The fused map is rasterized to form an obstacle map. For the obstacle map, firstly, binarization is performed to obtain the obstacle as shown in Figure 5(a), and then the distance of the binary image of the obstacle is transformed. Distance transformation describes the distance between a pixel in an image and a region block. The pixel value in the region block is 0. The pixel value near the region block has a smaller

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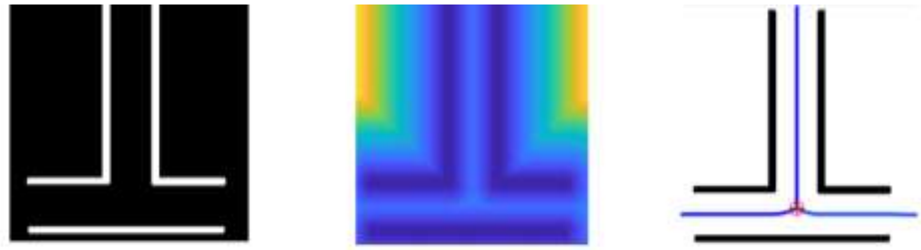
value. The farther away from it, the larger the value. Taking the binary image as an example, the pixel values inside the area block are 1, and the other pixel values are 0. Distance transformation gives the distance between each pixel point and the nearest area block boundary, and the result of distance transformation inside the area block is 0, as shown in Figure 5(b).

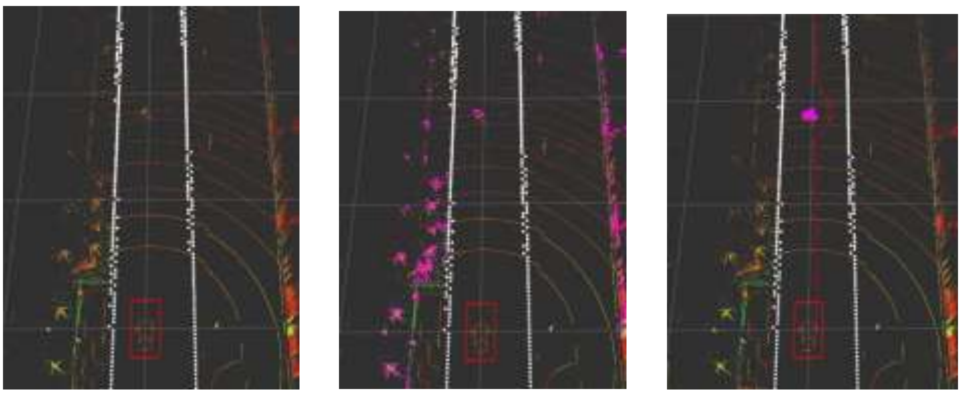
Then, the watershed algorithm is used to obtain the obstacle topological map. The basic idea is that the image is regarded as the topological landform in geodesy. The gray value of each pixel in the image indicates the height of that point, and each local minimum and its affected area are called water-collecting basin. The core of watershed method is that the boundary of the water-collecting basin generates a dividing line to form a watershed. By simulating the immersion process, the watershed algorithm constructs a dam at the confluence of two water collecting basins to form a watershed, and the watershed curve obtained is the road network curve. Topological map is a geometric description of road network information. It refers to the path with curves, and the map formed by curves is the road network map. Intersections of different paths are called nodes. The topological curve is the midline of obstacles on both sides, as shown in Figure 5(c).



(a) Obstacle map (b) Distance transformation (c) Topological curve

Fig 5: Topological map construction

The result of path planning on the constructed topological map is shown in Figure 6. The red rectangle is the location of the unmanned vehicle; (a) is the prior map, and (b) is the result of fusing the obstacle map with the current location. The red dotted line in (c) is the planned path. It adjusts the path according to the obstacles appearing in the current obstacle map to form an arc path to avoid obstacles.



(a) Prior map (b) Fusion map (c) Path planning results

Fig 6: Path planning using topological map

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VI. CONCLUSION

To solve the problem that the route planning of self-driving vehicles in mining areas requires constructing topological maps, the author proposed a fast method to construct obstacle topological maps. To meet the practical application demand of dynamic changes in mining scene, this paper adopts the combination of prior map and obstacle map to construct topological map. Firstly, according to the data of laser point cloud and inertial navigation sensor, the closed-loop detection is introduced to construct a high-quality prior map, and then the obstacle map is automatically constructed for obstacles in real-time positioning. After the prior map and obstacle map are fused, the topological map is constructed by morphological method for path planning. The experimental results show that the obstacle topological map constructed in this paper can effectively help path planning to avoid obstacles.

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