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Vehicle target clustering identification algorithm based on 3D Lidar point cloud

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***Abstract*— A new vehicle target clustering identification algorithm is proposed based on the characteristics of the elevation of the structured road area and the road boundary 3D point cloud collected by the 32-line laser radar and the projection characteristics of the three-dimensional point cloud data of the vehicle target in the structured road environment. Firstly, the algorithm divides the area of interest of the smart car into six regions based on the origin of the 32-line laser radar coordinate system: right front, right rear, right, left rear, left front, left side, and the road boundary is identified based on the established structured road model, thereby reducing the interference of the obstacle outside the road boundary to the identification of the vehicle target and improving the real-time performance of the data processing. Secondly, based on the characteristics of the point cloud data of the target surface of the laser radar and the shape projection characteristics of the vehicle target, the clustering algorithm of the distance threshold is adjusted by the adaptive region. The distance threshold can be automatically based on the different regions of interest adjustment. Finally, the vehicle target is accurately identified by extracting the internal feature points of the clustering target and calculating the angle of the feature point vector or the length of the module. Experimental results show that the proposed algorithm can accurately identify the vehicle target in the structured road area, and the accuracy and robustness of the vehicle can meet the requirements of the vehicle.**

***Index Terms*— intelligent vehicle, laser radar, Schweller process smoothing algorithm, adaptive clustering**

I. INTRODUCTION

With the continuous development of artificial intelligence, sensor technology and control system, unmanned vehicle driving platform technology research has made great progress [1]. Accurate detection of intelligent vehicles around the area of interest within the vehicle size, location and speed and other information is the basis of vehicle-assisted driving system, it is one of the key technologies of intelligent vehicle navigation.

At present, the vehicle identification algorithm mainly has the feature description and the grid map based method. Based on the multi-line laser radar to collect the surrounding obstacle point cloud detection vehicle target, mainly through clustering, geometric feature fitting, extraction of eigenvectors and other steps to achieve. However, a geometric feature model can only correspond to identify a class of targets, so the method based on feature description is less versatile. Fayad [2] and others based on 2D laser radar collected point cloud data, the use of model target shape to identify the vehicle, but did not consider the vehicle driving due to changes in the direction of the target shape changes, and thus the reliability of the algorithm is poor. Azim [3] and others proposed based on multi-line laser radar collection of obstacle point cloud, using long height, aspect ratio and other characteristics to identify the vehicle. In the actual environment, due to obstruction caused by the original long high proportion of high aspect ratio is destroyed, so the accuracy of the method to be improved. Gan Zhimei[4] and others proposed the use of clustering algorithm combined with vehicle rectangular projection and its speed characteristics to identify the vehicle, and through experiments to prove the effectiveness of the algorithm. Kagesawa[5], based on the vector quantization proposed by Krumm, identifies the vehicle by matching the local characteristics of a set of input images with the training images of a given target vehicle. The algorithm has a higher identification rate for the obscured vehicle targets, but the robustness is poor. Jianfeng Sun [7] and others proposed to use the maximum average correlation height filter on the laser radar simulation distance image for Gaussian noise suppression, the use of distance classification correlation filter on the unknown target classification and identification. Douillar[8] and so on based on the hybrid height map can be better to extract the ground, obstacle information, but this method requires a higher external radar calibration, vulnerable to changes in vehicle posture.

According to the characteristics of structured roads, a new method of vehicle target identification is proposed based on the three-dimensional point cloud data of obstacle targets in the region of interest of target vehicle that collected by laser radar.The vehicle target is identified by extracting the internal feature points of the clustering target and calculating the angle of the feature point vector or the length of the module.

II. ROAD BOUNDARY IDENTIFICATION PRINCIPLE

1.1 Introduction to the 32-line laser radar

HDL-32E laser radar is a multi-beam three-dimensional imaging laser scanning system, is widely used in unmanned areas. The lidar uses the motor to rotate the data to collect data, used to detect the surrounding 360 degrees within the obstacle information. Its detection range: the vertical direction of the visual range of 41.3 °, the horizontal field of view up to 360. Angle resolution 0.09 °; distance accuracy: 2 cm; The radar coordinate system settings, as shown in Figure 2:

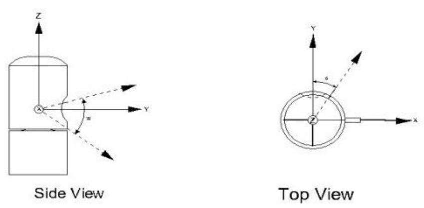


Fig.2 HDL-32E lidar coordinate system settings

1.2 32-line laser radar point cloud data characteristics

HDL-32E radar is the rotation of the surrounding environment data in spherical form as : $R=\{(r_n,\omega_n,\alpha_n)|n=0,1...R_n\}$, As shown in Figure 3. Ω is the vertical angle of the point, corresponding to the laser id, α is the horizontal angle of the point, and is the current rotation angle position of the radar. The collected data is converted to three-dimensional coordinates (X, Y, Z),the direction of the unmanned driving vehicle is the Y direction, and the direction perpendicular to the traveling direction of the unmanned vehicle is the X direction.

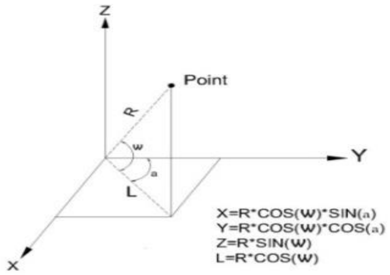


Fig. 3 Ball coordinate set principle

In the actual collection of HDL-32E laser radar, according to the location of the surrounding vehicle relative to the target vehicle, the radar can usually scan to 1 or 2 vehicle side, the collection of the surrounding environment point cloud data has the following characteristics: 1) radar point cloud data is massive. 2) Radar massive cloud data is tiered storage. 3) The horizontal resolution of the radar determines the distance between the point cloud data and the distance from the target to the sensor is proportional. 4) The vertical resolution of the radar determines that the vertical distance between the adjacent cloud data is proportional to the distance from the target to the sensor. 5) tires, the location of the window reflectivity is low, point cloud data sparse and not continuous. Therefore, in order to save data storage space and does not affect the identification of vehicle characteristics. This paper extracts the target 3D point cloud information within a certain Z coordinate range and projects it onto the xoy plane.

According to the characteristics of the HDL-32E lidar cloud, the internal point cloud data distance of the target clustering far away from the unmanned vehicle is obviously larger than the internal point cloud data of the target clustering near the distance. For the same vehicle target, the point cloud data is relatively dense (as shown in clusters 2, 4, 5 and 7 in Figure 4) on the sides that are approximately perpendicular to the direction of the laser beam. In the same way as the direction of the laser beam, the point cloud data is relatively sparse and discontinuous (as shown in the elliptical region in Figure 4).

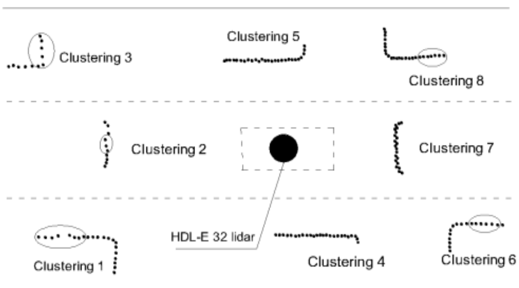


Fig. 4 Radar scan vehicle target plan view

III. DISTANCE-BASED CLUSTERING ALGORITHM

Based on the characteristics of laser radar scanning vehicle target point cloud data, this paper adopts distance-based clustering algorithm. In [4], the method of adapting the distance threshold is proposed, and the formula is

$$D_{\max}=r_{n-1}\frac{\sin(\Delta\phi)}{\sin(\lambda-\Delta\phi)}+3\sigma_r \qquad (1)$$

In the formula (1): r_{n-1} is the depth value of point p_{n-1}; σ_r is the lidar measurement error; $\Delta\phi$ is the angular resolution of the lidar; λ is the threshold factor. Obviously the value of λ determines the size of the distance threshold. First calculate the distance between the successive points of the obstacle surface at a certain distance, reverse the value of λ, and then in the program according to the actual data for offline adjustment.

After determining the threshold factor λ, the distance threshold calculated by the formula (1) is automatically adjusted only with the depth of the scanning point, and the scanned surface is independent of the relative azimuth of the laser radar. As the angle resolution of the lidar changes with the relative azimuth and distance of the surrounding vehicle and the lidar, the clustering method of [4] is used when the surrounding vehicle is located at the left, right, right and right rear areas of the target vehicle, The probability of clustering the front and side of the same vehicle is greatly reduced. Therefore, this paper proposes a clustering algorithm to improve the distance threshold by adaptive region selection based on the method of improving the distance threshold according to [4]. Prior to clustering, the scene of unmanned vehicles should be defined for better clustering of vehicles in areas of interest for unmanned vehicles.

This article to three lane scenes (shown in Figure 5) as an example, based on the origin of the radar mounted on the roof of the unmanned vehicle C1. The area of interest of the target car is divided into the left front region (A left lane area starting from a horizontal line with a horizontal straight line with a distance of 0.5 m parallel to the front bumper of the unmanned vehicle), the left area (parallel to the horizontal line between the front bumper of the unmanned bumper and the horizontal dashed line with a distance of 0.5 m and the horizontal lane between the horizontal dashed line parallel to the horizontal line of the bumper of the unmanned rear and the distance of 0.5 m),left rear area (in the left lane area parallel to the horizontal dashed line where the bumper is horizontal and the horizontal dashed line is 0.5 m),the right front area (the right lane area with a horizontal line parallel to the horizontal line with a horizontal line of 0.5 m from the front bumper of the unmanned vehicle) ,the right area (parallel to the horizontal lane where the front bumper of the unmanned bumper is horizontal and the distance is 0.5 m and the horizontal right line between the horizontal dashed line parallel to the horizontal line of the bumper of the unmanned rear and the distance of 0.5 m), right rear area (the right lane area at the horizontal line with a horizontal straight line with a horizontal line of 0.5 m parallel to the rear bumper of the unmanned vehicle).

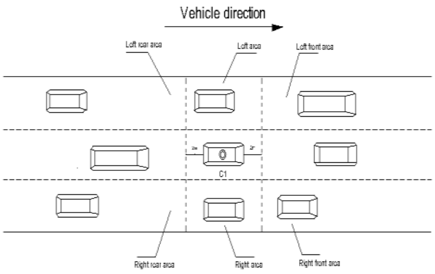


Fig.5 Three lane target car C1 traffic scene map

In the process of clustering, the first point of the search is based on the nearest point of the radar origin, and if the area does not search for the nearest point, the output is not the target vehicle; If a region search to the nearest point, and then according to the point of the x, y coordinates to determine whether the target car is located in the region, if it is, then the output of the target car, otherwise the output area without a target car; When it is judged that there is a target vehicle in the area of interest of the target vehicle, it is assumed that the target vehicle left front area has a target vehicle, and the target vehicle is clustered according to the distance-adaptive clustering method proposed in [4].The steps are as follows: Firstly, the slope of the connection between two adjacent points is calculated, and the slope of the connection is preprocessed by Xiao Weier data smoothing algorithm, eliminate the abnormal value caused by the plane of the vehicle plane, as shown in Figure 6.

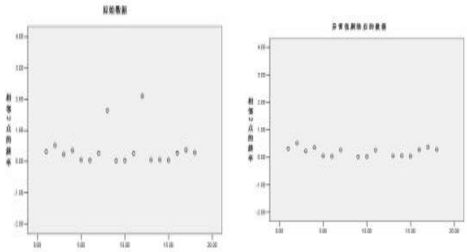


Fig.6 Schweller algorithm for the results of the slope of the connection process

If the connection slope k after the pretreatment is smaller and the slope of the connection is in the range of $k \pm \beta$, the adjacent two points are likely to be located on the front of the vehicle, and the threshold factor λ takes a larger value to calculate a smaller distance threshold. If the connection slope k is pre-processed by the Schweller data smoothing algorithm, then the adjacent two points are likely to be on the side of the vehicle, and the threshold factor a is smaller, and a larger distance threshold is calculated.

After the cluster is completed, the internal distance of the clustering target in different regions is calculated according to $d = \sqrt{x_{PniPne}^2 + y_{PniPne}^2}$ according to the area of interest of the target vehicle. In the formula: P_{ni} represents the starting point of the cluster; P_{ne} represents the end of the cluster. For targets located within the front, front, left, and right side of the target, the internal distance of the target is less than 0.5 m, and is directly classified as a non-vehicle target; For targets located at the left, right, right, and right rear regions of the target, the internal distance of the target is less than 1 m, and is directly classified as a non-vehicle target.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

3.1 Experimental platform and parameter setting

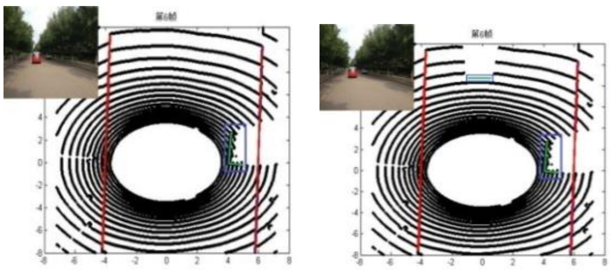
In order to verify the effectiveness of the proposed algorithm, Tang Jun electric vehicle $EV02$ loading $HDL-32E$ laser radar as the experimental platform, real car data acquisition experiments were carried out in the Shandong University of Technology campus, speed control in 30km / h, radar scanning frequency is set to $10Hz$.

Fig.7 Experiment platform with lidar

3.2 Analysis of experimental results

The validity of the proposed clustering algorithm is proved by experiments. In the clustering algorithm proposed in this paper, the threshold parameter λ is set to 9 ° for adjacent points on the front side of the vehicle. For the adjacent points on the vehicle side, the threshold parameter λ is set to 3 °. The comparison between the vehicle identification result using the adaptive distance threshold algorithm and the vehicle identification result proposed by the clustering algorithm proposed in this paper. In the former, the Schweller data smoothing algorithm is used to preprocess the slope of the adjacent two points within the target cluster, and the outliers due to the bumps of the vehicle surface and the obstacles in the environment are eliminated. Then, based on the trend of the adjacent 2-point slope in the target cluster, it is judged whether it meets the characteristics of vehicle surface contour. If it is satisfied, the threshold factor λ is changed according to the slope of the adjacent 2 points within the target cluster (The slope of the adjacent 2 points in the target cluster is larger, the threshold parameter λ is set to 9 º, and the threshold parameter λ is set to 3 º).

It can be seen from the experimental results in Figure 8, compared with the fixed distance threshold clustering algorithm, this paper proposed a higher accuracy of clustering methods. By using the distance-based adaptive clustering method and the multi-feature fusion target identification method proposed in this paper, it is possible to accurately identify vehicle targets with different distances and azimuths.



（a）Single vehicle target identification　（b）Dual vehicle target identification

Fig. 8 Vehicle target identification

V. Conclusion

Aiming at the problem of vehicle target recognition in intelligent vehicles in structured roads, this paper presents a new vehicle target clustering algorithm. Experimental results show that the algorithm can accurately identify the vehicle target in the structured road area, and it can meet the requirements of the intelligent vehicle to detect the vehicle target. In the future study, in-depth study can be carried out from the following aspects:

(1) This paper only studies the identification of stationary vehicle targets, and should further study the identification of dynamic vehicles.

(2) In this paper, only the use of laser radar sensor, in the future research should be combined with multi-sensor information fusion, in order to further improve the accuracy of the algorithm.

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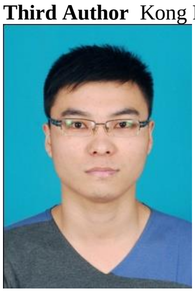

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