International Journal of Engineering and Advanced Research Technology (IJEART)
ISSN: 2454-9290, Volume-3, Issue-6, June 2017

Vehicle target identification algorithm based on 3D laser radar

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***Abstract*— Aiming at the problem of vehicle target identification in structured road environment, a new vehicle target identification algorithm is proposed based on the contour projection characteristics of obstacle target cloud obtained by 3D laser radar. Firstly, this method uses the label method to determine the classification number of the target point cloud, and then uses the K-means clustering method to classify the obstacle objects. Secondly, the internal feature points of the clustering target are extracted, and calculate the angle of the feature point vector or the length of the module, and then accurately identify the vehicle target. The experimental results show that the proposed algorithm not only can accurately identify the vehicle target in the structured road area, but also effectively suppress the interference of the obstacle and verify the effectiveness of the algorithm.**

***Index Terms*— intelligent vehicle; laser radar; kruskal method; K-means clustering; vehicle identification**

I. INTRODUCTION

The perceived demand for obstacle information in the area of interest for a intelligent vehicle is multi-faceted, obstacle identification and dynamic obstacle tracking are an important part of intelligent vehicle environment perception technology. Accurate identification of the location and speed information of the vehicle target in the area of interest of the intelligent vehicle is the basis for the implementation of the vehicle-assisted driving system, it is one of the key technologies of intelligent vehicle navigation.

Depending on the sensor used, the identification of vehicle targets generally includes vehicle target identification based on the camera passive sensor, vehicle target identification of the LIDAR active sensor, and vehicle target identification that fuses the two. The vehicle target recognition algorithm based on camera passive sensor is susceptible to environmental factors, which is sensitive to changes in weather conditions and poor data processing. However, the LIDAR active sensor not only has the advantages of wide detection range, high resolution and three-dimensional coordinates, distance and so on, and is less affected by the environment. Therefore, this paper is based on the three-dimensional point cloud projection feature of the obstacle target in the structured environment that collected by the 32-line laser radar to identify the vehicle target.

At present, the algorithms for identifying vehicle targets are mainly based on feature description and raster map method. the vehicle target algorithm that based on the three-dimensional point cloud data collected by multi-line laser radar, is realized by clustering, extracting feature vector and geometric feature fitting. However, a geometric feature model can only correspond to identify a target, therefore, the method based on feature description is less versatile. Anna[1] and others established a model describing the geometric characteristic attributes of vehicle targets and estimated them using Bayesian networks. Considering the influence of the acquisition location on the vehicle target point cloud, a central point updating algorithm is proposed to correct. This method does not consider the influence of vehicle target attitude change, so the reliability of the algorithm is poor. Himmelsbach[2] and others proposed a dynamic vehicle target identification based on the overall strength characteristics of the object and the highly stratified covariance eigenvalues based on the three-dimensional point cloud of the road environment collected by radar. Azim[3] and others used long, aspect ratio and other characteristics to identify the vehicle. In the actual intelligent vehicle driving road environment, due to obstruction caused by the original long, high aspect ratio is destroyed, so the accuracy of the method to be improved. Gan[4] and others proposed that the clustering algorithm should be used to solve the problem of vehicle identification when the target is obstructed by obstruction. Combining with the rectangular projection and velocity characteristics of the vehicle, the experiment proves that the algorithm has some robustness. Chen Xiao qing[5] and others proposed the use of singular value of the laser imaging target recognition algorithm, by analyzing the relationship between the recognition rate and the number of singular value features, the singular value feature is extracted from the distance image of the laser radar imaging target. Finally, the optimal parameter support vector machine is used to identify the vehicle target. Simulation results show that the recognition rate of the algorithm is relatively high, but the real - time performance is low. Amirali[6] and others proposed probabilistic modeling of moving objects based on scene characteristics and vehicle motion model by et al, And the HMM is used to separate the target vehicles from the background and track them in probability. Experimental verification shows that the method is robust. Chen Xiaoqing[7] and others proposed based on two-dimensional wavelet transform target recognition algorithm. Firstly, the two-dimensional wavelet transform is carried out on the distance of the target. Then the singular value feature is extracted. Finally, the genetic algorithm is used to optimize the parameters of the support vector machine and identify the ground target. Experimental results show that the effect of recognition is significantly improved compared with the previous algorithm, which is based on the singular value. Sun[8] and others proposed to use the maximum average correlation height filter combined with the distance classification correlation filter to identify and identify unknown targets. Simulation results show that the algorithm is robust, but when the target is blocked, the recognition rate of the algorithm is reduced. Chen[9] and others use the improved 2D virtual scan to detect dynamic objects, match the likelihood field model for each dynamic vehicle target, and classify the dynamic objects using the motion evidence and motion consistency of the fitted vehicle. The method can be divided into multiple categories of obstacles, and then identify the vehicle target, but the calculation is large. F[10] and others proposed a vehicle detection method based on a laser point cloud using a probability hypothesis density (PHD) filter, which consists of two stages: a hypothesis generation phase for detecting a potential object and a hypothesis verification phase for classifying the object. Experimental results show that the algorithm can accurately identify vehicle targets in complex scenes.

According to the characteristics of structured road environment, based on the 3D point cloud data of the obstacle target in the area of interest of the intelligent vehicle that collected by the 3D laser radar, the vehicle target recognition method is presented in this paper. This method uses the kruskal method to classify the target point cloud of the obstacle, and then combines the K-means clustering algorithm to cluster the target point cloud that the classification number determined. In view of the existing vehicle target recognition algorithm is more complex, real-time poor defects, a vehicle target method based on the projection feature of vehicle target is proposed. This method extracts the internal feature points of the clustering target and calculates the angle of the feature point vector or the length of the module, and then identifies the vehicle target. The experimental results show that the recognition algorithm is more accurate and robust.

II. INTRODUCTION TO THE 32 LINE RADAR

1.1 Parameters and coordinate system

HDL-32E lidar is a multi-beam three-dimensional imaging laser scanning system, which is widely used in unmanned and three-dimensional maps and other fields. The laser radar uses the motor to rotate the data to collect data, which can detect the obstacle information the within surrounding 360 degrees. It has a 32-line laser scanning beam (32 pairs of laser launchers and laser receivers) arranged in the vertical direction, composed of 16 scanning lines from the upper and lower groups, and each has a laser receiver mirror, each scan line has its fixed pitch angle. The range of HDL-32E lidar sensor detection: the vertical direction of the visible range of 41.3 °, the horizontal field of view up to 360 °. angle resolution 0.09 °; distance accuracy: 2 cm. The HDL-32E lidar sends measurement data through the UDP protocol and outputs UDP packets. Each packet contains the distance information and angle information returned by each laser beam. The HDL-32E lidar coordinate system, as shown in Figure 1:

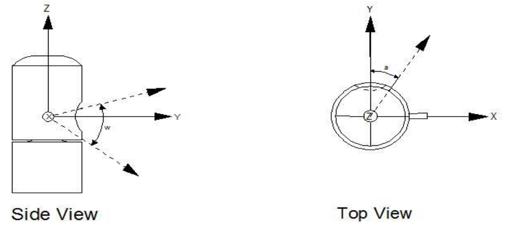


Fig. 1 HDL-32E lidar coordinate system

HDL-32E lidar is the rotation of the collection of road environmental information, the collected point cloud data in spherical coordinates of the form: $R=\{(r_n,\omega_n,\alpha_n)|n=0,1...R_n\}$, as shown in Figure 2. ω is the vertical angle of a point in the cloud, which corresponds to the id of the laser, and α is the horizontal angle of a point in the cloud, which is the current rotation angle of the lidar. The collected point cloud data is converted to three-dimensional coordinates (X, Y, Z), Y represents the direction of the unmanned driving, the direction of X is perpendicular to the direction of the unmanned driving, and the direction of Z is perpendicular to the xoy face.

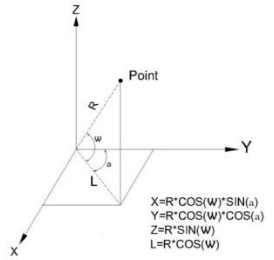


Fig. 2 Radar ball coordinate system schematic diagram

III. STRUCTURED ROAD BOUNDARY RECOGNITION

2.1 Structured road model

In the actual point cloud of the structured road environment collected by the lidar, the impact of obstructions on both sides of the road relative to the obstructions in the road area to vehicle targets is almost negligible. As the 32-line laser radar to collect the massive road environment cloud data required storage space and affect the real-time data processing. Therefore, in order to save data storage space and improve the real-time data processing, it must first identify the road boundary.

In a structured road, there is a noticeable point cloud elevation change between the road area and the road boundary collected by the radar, and the change in the elevation is a regular transition. During the normal driving process of the target vehicle, structured straight boundary 3D point cloud data collected by the radar projected to 2D Plane Approximately Straight Line. Figure 3 is an ideal structured straight road model. Before recognizing the road boundary, it is assumed that the change of the road width and its curvature in the time of lap rotation (0.1s) is negligible, and the left and right sides of the road are approximately parallel.

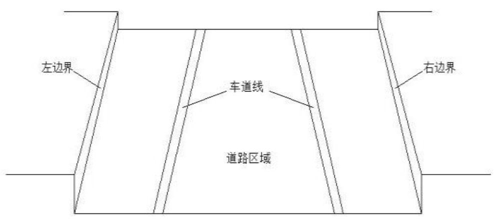


Fig.3 Structured road model

2.2 Road boundary recognition principle

The structured straight road boundary identification is divided into the following five steps:1、Based on the radar installed in the height of the target car roof, extract the [a, b] range of three-dimensional point cloud in the interest area of the target car; 2、Fitting the road area; 3、Extract the coordinates of the four vertices of the fitting road area plane; 4、The x-coordinate is a negative point of the two points, x-coordinate positive point of the two points were connected into a straight line respectively, and were recorded as:

$A_1x+B_1y+C_1=0, A_2x+B_2y+C_2=0$; 5、To determine the straight road boundary: 1) Calculate the angle between the two lines and the x-axis of the body coordinate system and determine whether the angle is near the right angle; 2) If the angle is close to the right angle, let $A_1=A_2, B_1=B_2$; 3) Calculate the distance $d=\frac{|C_1-C_2|}{\sqrt{A_1^2+B_1^2}}$ between the two straight lines and determine whether d_1 and d are approximately equal according to the actual straight road width; If $d_1 \approx d$, the left and right borders of the straight road can be replaced by the straight lines $A_1x+B_1y+C_1=0$ and $A_2x+B_2y+C_2=0$ can replace.

IV. VEHICLE TARGET CLUSTERING AND IDENTIFICATION

3.1 Vehicle target clustering

Based on the identification of the road boundary, in order to further save the data storage space, reduce the trough, the window reflectivity is low lead to radar point cloud data collected sparse, discontinuous defects and does not affect the vehicle target contour projection characteristics, According to the three-dimensional point cloud data of the target of the obstacle collected by the laser radar, the three-dimensional point cloud of the obstacle target within a certain coordinate range is extracted and projected onto the xoy plane: 1、measuring the height of the radar mounted on the roof; 2、According to the elevation of the window to the wheel brow under the different types of vehicles listed in table 1, and extract the vehicle under the window to the wheel eyebrow elevation within the $z\in[-z_3,-z_4]$ range of the point cloud. 3、Cast the point cloud within the $z\in[-z_3,-z_4]$ range onto the xoy plane. The point

Table 1 Parameters for different models

type	length（m）	width(m）	height（m）	The height between the window and the below wheel eyebrows（m）
coupe	4.1-4.4	1.6-1.7	1.3-1.5	0.65-0.85
Subcompact car	4.3-4.7	1.7-1.8	1.3-1.5	0.7-0.9
compact car	4.6-4.9	1.7-1.9	1.3-1.6	0.7-0.9
intermediate car	4.8-5.2	1.8-2	1.4-1.6	0.7-0.9
off-road vehicle	4.0-4.8	1.8-22	1.7-2.2	0.8-1.2

Taking into account the 32-line laser radar collection point cloud data with hierarchical, according to time series storage, The kruskal method is used to classify the point cloud in the range of $z\in[-z_3,-z_4]$, and then the K-means clustering algorithm is used to classify the obstacle target cloud. First determine the number of obstacle target cloud classification K, the specific steps are as follows: 1、Will have been projected to the xoy plane and belong to the range of $z\in[-z_3,-z_4]$ point cloud data in accordance with the time series in turn connected; 2、Calculate the distance between adjacent two lines; 3、According to the distance between two adjacent lines, in turn remove the adjacent two points of the line until the distance between the two adjacent lines of the line is less than the set distance threshold $D_{\min}$ and in turn mark the removed line ends ($i=1,2...n$); 4、 the number of obstacle classification is calculated, and then the K-means clustering algorithm is used to classify the obstacle target cloud.

3.2 Feature point extraction and vehicle target recognition

After the clustering is completed, based on the characteristics of vehicle target contour projection based on lidar scanning, that is, radar scanning the target vehicle in different directions of the vehicle can be scanned to one or both sides; If a side, then the vehicle target contour projection approximation of a certain length of the straight line, if the two sides, the vehicle target contour projection is approximately an L-shaped fold line with an angle of approximately 90 degrees. 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, the vehicle target is identified.

After the vehicle target clustering classification is determined, the internal feature points of K clustering target are extracted. The feature points include the coordinates of the interior point of the cluster target and the geometric characteristics of the interior point composition vector of the clustering target, which includes three variable information: 1、the coordinates of the interior point of the clustering target. 2、 the geometric characteristics of the vector composition contained in the clustering target. 3、 the size of the vector model included in the cluster target. Specific steps are as follows: 1) Extract the points marked in each cluster target, labeled as: $(x_i,y_i),(i=1,2...n)$; 2) According to the origin of the radar coordinate system, extract the nearest point from the radar origin $(x_j,y_j),(j=1,2...n)$; 3) Define the vector: $\begin{cases}\vec{a}=(x_j-x_i,y_j-y_i),\vec{b}=(x_j-x_{i+1},y_j-y_{i+1})\\ i=1,2..n;\ j=1,2...n\end{cases}$, And calculate the cosine of the angle between the $\vec{a}$ and $\vec{b}$ vectors:

$$\cos\theta=\frac{\vec{a}\cdot\vec{b}}{|\vec{a}||\vec{b}|} \quad (2)$$

In formula (2): $|\vec{a}|=\sqrt{(x_j-x_i)^2+(y_j-y_i)^2}$, $|\vec{b}|=\sqrt{(x_j-x_{i+1})^2+(y_j-y_{i+1})^2}$，$i=1,2...n$，$j=1,2...n$ .4）If $\cos\theta$ is close to 0, the preliminary determination of the cluster target for the vehicle, otherwise the target is non-vehicle. If $\cos\theta$ is close to -1, then the preliminary determination of the cluster target for the vehicle, otherwise the target is non-vehicle; 5) extract the three points that make the cosine of the vector angle close to 0,

And to connect (x_i,y_i)，(x_{i+1},y_{i+1}) two points of the line for the diagonal rectangle; If the length of the rectangle to meet the size of the models listed in Table 1, then determine the cluster target for the vehicle, otherwise non-vehicle; 6) Extract the three points that make up the cosine of the vector angle close to -1, define the vector $\vec{c}=(x_i-x_{i+1},y_i-y_{i+1})$, and calculate $|\vec{c}|=\sqrt{(x_i-x_{i+1})^2+(y_i-y_{i+1})^2}$; If $|\vec{c}|$ satisfies the dimensions of the models listed in Table 1, it is determined that the cluster target is a vehicle, otherwise it is a non-vehicle.

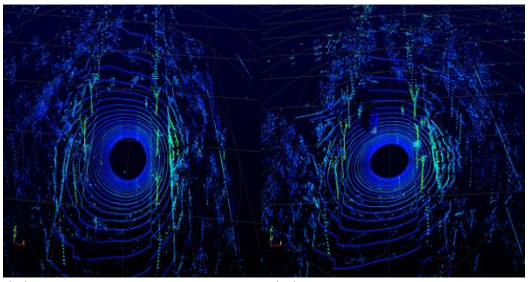
V. Experimental Verification and Discussion

4.1 Verification of road boundary recognition

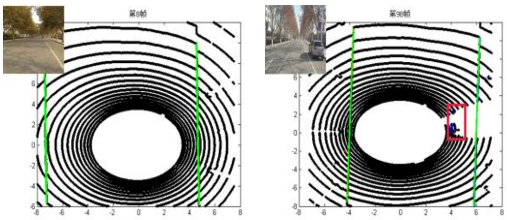
In order to verify the effectiveness of this algorithm, the Tang Jun electric vehicle EV02 is loaded with the HDL-32E lidar as the experimental platform, as shown in Fig 4.

Fig.4 Experiment platform with lidar

Figure 5 (a) and Figure 5 (b) were the radar collection of structured straight road environment without vehicle targets and vehicle targets of the original three-dimensional point cloud respectively; Figure 5 (c) and Figure 5 (d) show the structural straight boundary identification without obstacle occlusion and obstacle occlusion. The green curve is the identified road boundary, and the red rectangle is the vehicle target (representing the obstacle). It can be seen that the algorithm can accurately identify the road boundary and identify the distance of about 16 m under the condition that the road is smoother and the obstacle interference and the road width are almost constant. This algorithm overcomes the influence of interference factors such as lighting environment, vehicle movement state, camera angle and so on, which is based on the camera body's road boundary recognition algorithm, the algorithm accuracy and robustness are better.



（a）The original point cloud of the road boundary is obscured （b）Tthe original point cloud of the road boundary is not obscured



（c）No obstructions （d）Have obstructions

Fig.5 Identification of structured straight boundary

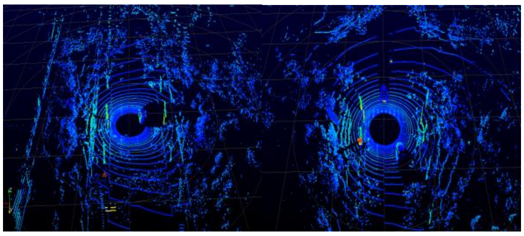
In order to verify the accuracy and robustness of the proposed algorithm, the 3D data of the 310-point environment point in the structured road environment collected by the radar are processed. Compared with the proposed algorithm performance and the performance of the proposed algorithm [11], as shown in Table 2:

Table 2 Algorithm performance

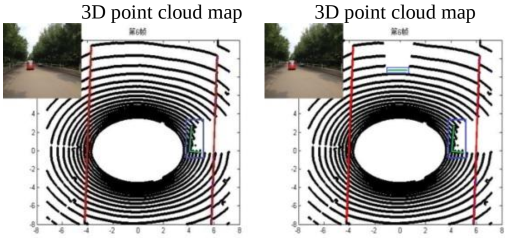
Road environment	The accuracy of the algorithm proposed in this paper（%）	The accuracy of the algorithm proposed in Document [11]（%）
Straight road boundaries are not obstructed by obstacles	95	90
Straight road boundaries are obstructed by obstacles	82	70

4.2 Vehicle target recognition verification

According to the feature points of the extracted clustering objects and the characteristics of the constituent vectors, the clustering objects are identified by the method of feature fusion. Figure 6 is the target of the structured road area, and the blue rectangles represent the identified targets, and the green polyline represents the eigenvector of the feature points within the cluster.



（a）Road environment with a single vehicle target original 3D point cloud map （b）Road environment with a dual vehicle target original 3D point cloud map



（c）Single vehicle target （d）Dual vehicle target

Fig. 6 Vehicle target identification

Figure 6 (a) and Figure 6 (b) are the original three-dimensional point cloud images of the single and dual vehicle targets in the structured straight road environment collected by the lidar. Figure 6 (c) shows the identification of a single vehicle target on the left side of the test vehicle, where the radar can scan both sides of the vehicle target.. Fig. 6 (d) shows the identification of the double vehicle target at the front side and the left front side of the test vehicle, respectively. As can be seen from the figure, the radar can only be scanned to one side of the front side vehicle, while the vehicle on the left side can be scanned for both sides. It can be seen from the experimental results that the algorithm can accurately cluster the vehicle targets in different locations for recognition within the target area of interest.

This algorithm is based on Intel i5 processor in Matlab7.0 experimental verification, the process of identifying a frame of data is 60ms, which is less than the general intelligent vehicle decision cycle 100ms, so the real-time performance is better.

VI. Conclusion

Vehicle target clustering and identification are an important part of intelligent vehicle environment perception technology. On the existing vehicle target recognition algorithm vulnerable to environmental impact, real-time poor defects, a algorithm for identifying target classification based on lidar is presented. The kruskal method is used to determine the number of obstacle target classification in this algorithm, and then combines with the K-means algorithm to cluster the obstacle target point cloud that the number of obstacle target clusters has been determined. Secondly, the internal feature points of the clustering target are extracted and the angle of the feature points is computed. The experimental results demonstrate that the recognition algorithm realizes the intelligent vehicle to identify the vehicle object more accurately and quickly.

In the future study, should be studied from the following aspects:

(1) This algorithm only applies to structured straight road environment, in order to improve the accuracy of road boundary and vehicle target recognition, we should further integrate the multi - sensor information fusion,

(2)This algorithm can only identify the single-frame static road boundary and vehicle target collected by lidar. In the follow-up study, we should consider the recognition of dynamic target to further improve the robustness of the recognition algorithm.

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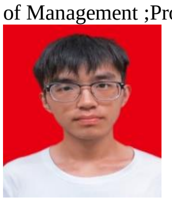

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