A new Construction Method of Vehicle Digital Camouflage Spraying Model

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Abstract. Digital camouflage plays an important role in improving the combat performance of vehicles. The reconstruction of the spraying model of the automobile surface can improve the automation level of the digital camouflage painting operation. The surface digital camouflage spraying model construction method is a processing flow that incorporates a variety of technical methods, including surface point cloud data collection technology, point cloud synthesis and segmentation method, surface model reconstruction method and spray pattern fusion technology. Four linear laser sensors are used to scan the vehicle surface to obtain the local point cloud data of the vehicle. The vehicle CAD model and the painting pattern figures are analysed. And the region growing segmentation method is used to subdivide the scanned point cloud data. For the point cloud after partitioning, the point set of the digital camouflage pattern is directly searched by using the constructed discrete metric. Then each point cloud is merged with the 2D camouflage pattern to obtain the digital camouflage spraying model of the vehicle surface.

1. Introduction

At present, the vehicle digital camouflage needs manual spraying. In order to improve the automatic spraying level of digital camouflage pattern, it is necessary to integrate the designed two-dimensional camouflage pattern with the real vehicle surface. The construction process of vehicle surface Digital Camouflage spraying model mainly includes the collection of vehicle surface coordinates, the combination and segmentation of vehicle surface point clouds, surface mapping and some other steps.

There are many data acquisition methods. For a method based on the principle of time of flight, X Zhao¹ scans some large buildings with an accuracy of 5 mm. For the phase modulation method, L Zhang² uses 31 phase laser displacement sensors to measure the external contour of a 23.5-meter-long train body with an accuracy of 3 mm. For the structured light method, Agin³ has realized scanning with depth resolution of 0.5 mm. For the multi view image synthesis method, Soheilian⁴ reconstructed the road traffic signs with an average accuracy of 35 mm. For the laser light curtain measurement method, C Liang⁵ realized the measurement of the contour of a 8-meter-long car body, with the accuracy better than 1%.

In order to merge the local scan data into the whole vehicle point cloud, it is necessary to synthesize the data. The point cloud registration algorithms can be divided into two categories: rough registration method and precise registration method. For the rough registration method, for example, Rusu⁶ proposed the sampling consensus initial alignment(SCA-IA) method. And for the precise registration method, Besl⁷ proposed the iterative closest point(ICP) algorithm.
Point cloud segmentation is to classify the points in a point cloud. There are many methods. For example, the edge based segmentation method, which mainly calculates the local characteristics of points to detect boundary points, such as curvature step points, curvature local extremum, curvature zero crossing points, depth discontinuity points. Region based segmentation methods, for example, Adams\(^8\) proposed region growing segmentation method, Shrifman\(^9\) proposed k-means based segmentation method, and Golovinskiy\(^10\) proposed a segmentation method based on minimum cut theory.

There are 3 steps in our spray model construction method, as shown in Figure 1. Firstly, we need to set up the vehicle database. Based on the CAD model and spray patterns for each kind of vehicle, we construct the surface model of spray areas. Secondly, local point clouds are obtained via 2D or 3D laser sensors, and then are merged into the scanning point cloud model. Finally, the point cloud model is clustered by combining the key point information of the vehicle. Then the lattice centroid coordinates are solved, and the color information is fused to complete the construction of the spraying model.

![Figure 1. Flow chart of the spray model construction](image)

### 2. Vehicle model database

The original pattern model is generated in Inkscape, which is the 4-color pattern shown in Figure 2-a. The color of adjacent block boundary pixels is filled with the nearest block color, as shown in Figure 2-b. Both Figures have 2218 pixels in width and 333 pixels in height. Each pattern needs to be mapped to the corresponding vehicle surface, and then to be discretized to get the digital camouflage pattern.

![Figure 2. Spray pattern](image)
spraying area includes basement, turret and left/right sideboard. We calculate the key points for each spray area, such as the area boundary points, the area centroid points, etc.

a. Whole model  
b. Basement  
c. Turret  
d. Left sideboard  
e. Right sideboard  
f. Gun  
g. Tracks  
h. Wheels  
i. Others

Figure 3. Vehicle model analysis

3. Vehicle surface point cloud scanning

The vehicle size is about 10-m long, 4m wide and 3.5m high. The line laser sensor Gocat 2490 is selected to scan. The scanning angle of the sensor is 55 degrees, the angular resolution is 1920, the maximum scanning depth is 2.125 m, and the depth scanning accuracy is 27 microns. According to the size of the spraying part of the vehicle, we use 4 linear laser sensors to form the line laser light curtain, as shown in Figure 4-d. The sensors are labeled from 1 to 4, and each scan area is represented as a trapezoidal wireframe. The simulation of sensor scanning process with blensor is shown in Figure 4-a, and the subfigures (b, c, d) are different projection views.

Figure 4. Vehicle scan simulation

Point cloud synthesis consists of two parts. First, for each sensor, the sensor can only obtain two-dimensional information during scanning, and the other dimension information needs to be determined according to the vehicle and scanning frequency. For example, taking sensor 1 for example, according to the position and orientation of the camera coordinate system in the world coordinate system, the Y coordinate needs to be determined through the relative movement of the vehicle and the sensor. Then, according to the pose of each camera, the point clouds of multiple cameras are spliced to synthesize vehicle point clouds. As shown in Fig. 5, the data collected by each camera is represented as a color.
4. Spray model construction

The whole point cloud model of vehicle is segmented. Here we generate the segmentation of the original point cloud with region growing method. For example, Figure 6 shows the top 10 point clouds with the largest number of points. The original points are generated with linear scanners, it is better to generate voice points before the segmentation. Point sets need to be subdivided or merged according to their relative positions.

Figure 6. Segmentation of the vehicle point cloud

Figure 7-a shows the re-segmentation of the local point cloud, then the four sets can be combined into 2 sets. We use the red set and the green set in Figure 7-a to form the left sideboard, which is shown in Figure 7-b and Figure 7-c. The Figure 7-b is the clouds generated with the original clouds, the column resolution is 10 mm, the row resolution is determined by the angle resolution of the sensor and the deep distance between the surface with the sensor, which is set to 480 in 45 degrees. In Figure 7-c the resolutions of row and column are set to 15 mm, which reduce the amount of point set data and accelerate the calculation process.

Figure 7. Re-segmentation of the local point cloud

For each segmentation, a local reference frame is established to unify the processing flow of each spray area. Here we can use the sensor position matrix. Then the point cloud of each cluster is presented as deep map. Finally, we resample the cluster to a matrix and collect the coordinate of each lattice centroid. We can resample each cluster into different size, in Figure 8, we resample the deep map with
squares with the side length of 15 mm, then we calculate the lattices with the side length of 30 mm (Figure 8-a) and 100 mm (Figure 8-b).

![Figure 8. Spray surface](image_url)

5. Conclusions
We put forward the construction method of vehicle surface spraying model, and realize the following steps.

1. We use the linear laser sensors to collect the point cloud on the vehicle surface.
2. Classification of point cloud based on multi-sensor data fusion and point cloud segmentation.
3. The 2D spray pattern is used to construct the vehicle surface spray model.

6. Additional information

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