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Research of Environmental Perception Technology for Automatic Parking

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Abstract: In order to achieve parking position detection that plays a great important role in the automatic parking system and its accuracy directly affects the accuracy of path planning, this paper has put forward a method that can fast and accurate detect the parking position. Firstly, laser rangefinder was used for gathering environmental information around the vehicle and then median filtering and least square method were used for original laser data filtering, which can reduce noise interference. Finally, grid-based clustering method and K-means clustering method were used for detecting the feasible parking spaces. This paper simulated the two methods on the VC^{++} platform and made a comparative analysis of them. Experimental results show that this method has high robustness and accuracy.

Key words: Automatic parking, Environmental perception, Median filtering, Least square method, Grid-based clustering

INTRODUCTION

With the trend of rapid growth in the vehicle, parking space gradually becomes deficient. This situation is more serious, especially in the downtown area (He, 2009). It is very difficult to parking for a driver who is not good at driving in the shortage of parking space (Faiz and Hassan, 2009). For normal vehicle that has not parking assist technology, when parking, the methods, such as looking the rear-view mirror, getting someone's guidelines and turning the driver's head back, are generally used to help driver checking the situation of the rear of the vehicle (Kim and Kim, 2012). Because the observation scope of the rear-view mirror is limited and its effect is distorted, drivers often turn their head back to check the situation of the rear of the vehicle (Suhr *et al*., 2010). So parking becomes very tedious task, which leads the drivers who is not good at driving feeling confused (Garcia *et al*., 2011). Based on this reason, accidents occur frequently in the process of parking (Hitz *et al*., 2012). The accidents impair the interests of others and resulted in the loss of driver's economic and disrupt the public order in some extent (Choi *et al*., 2011). Parking Assist Technology (reversing radar, reversing image, automatic parking) gradually appeared in people's view in this background (Pietzsch *et al*., 2009) . The most of the tedious task of parking is done by the vehicle itself with the automatic parking technology (Stein *et al*., 2010). And the parking task can be safely and accurately completed through generally only operating the brakes and gear (Wang *et al*., 2007). So drivers will feel more comfortable, because it reduces the driving fatigue. And the safety performance will be better, because it reduces the incidence of traffic accidents in some extent (Shi and Wang, 2010). Song (2009), National University of Defense Technology, researched that the control system structure of automatic parking system, path planning, parking space detection and path accuracy, etc. Meanwhile, the methods combining experimental and theoretical method are used to verify the rationality of the theoretical structure. And that achieves a higher accuracy of parking. Wang (2010), University of Science and Technology of China, comprehensive and detailed researched the path planning of automatic parking system, then improved the research method depend on the results of path planning experiment. An adaptable path planning method of parking is achieved through continuous improvement and combined with the actual working conditions. Jiang and Zeng (2008), Shanghai Maglev Transportation Development Corporation and Tongji University researched the binocular vision method. Visual perception is used to identify viable parking space and this method was validated by experiments. Shi (2010), Shanghai Jiao Tong University, researched that the parking space detection based on lidar, path planning and path tracking, etc. And its core is Freescale S12 microcontroller, which achieves a good effect of parking verified through experiments.

LASER DATA PREPROCESSING

Due to the precision and environmental disturbances, there are defects in the sensor data. Namely the data acquired by sensor does not match with the actual

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environment, so that there is error about ambient information, which affects the accuracy of path planning. In order to improve accuracy of environment recognition, data preprocessing is required for most sensor data prior to data analysis. This paper combines the least square method and median filtering to achieve preprocessing.

Median filtering: The basic principle of Median filtering is that arranging the neighborhood data of a point in a digital image or a set of data, then finding the value location in the middle of the sequence and it is used to instead of the actual value at this point. According to this method, the data points of a digital image or a set of data were sorted and replaced. The median is defined as the following:

A set of data (digital image or digital sequence group) is $\{x_1, x_2, \ldots, x_n\}$, then n data of this group are arranged depend on the numerical size (descending order or ascending order):

$$y = \mathrm{Med}\{x_1, x_2, \cdots x_n\} = \begin{cases} x_{i\left(\frac{n+1}{2}\right)} & n \text{ is odd number} \\ \frac{1}{2}\left[x_{i\left(\frac{n}{2}\right)} + x_{i\left(\frac{n}{2}+1\right)}\right] & n \text{ is even number} \end{cases} \quad (1)$$

Least square method: The basic principle of least square method that is regression analysis method for short is minimum sum of squared error. Set (x_i, y_i) $(i = 0,1, \ldots, m)$for points of a set of data and $w_i>0(i = 0,1, \ldots, m)$ for the weight coefficient of each point. In function space $S=\mathrm{span}\{\phi_0(x), \phi_1(x), \ldots,\phi_n(x)\}$, ask for $S^*(x)$ in the formula (2) satisfy formula (3):

$$s^*(x) = \sum_{k=0}^{n} \alpha_k^* \varphi_k(x) \epsilon S(2) \sum_{i=0}^{m} \omega_i \left(s^*(x_i) - y^i\right)^2 = \min_{S(x) \in S} \sum_{i=0}^{m} \omega_i \left(s(x_i) - y^i\right)^2 \quad (3)$$

The method of acquiring function $S^*(x)$ is called least square method of data fitting.

The analysis of the two preprocesses methods: Median filtering method has a good filtering effect, while the least square fitting method has a good role in smoothing the data, so this paper combined the respective advantages of both methods to achieve better results of preprocessing that laid a good foundation for obstacle detection and parking space detection. As can be seen from Fig. 1, median filtering can filter a small amount of noise data (as shown in Fig. 1b) and then the least square method was used together, the data smoothing effect can be more ideal.

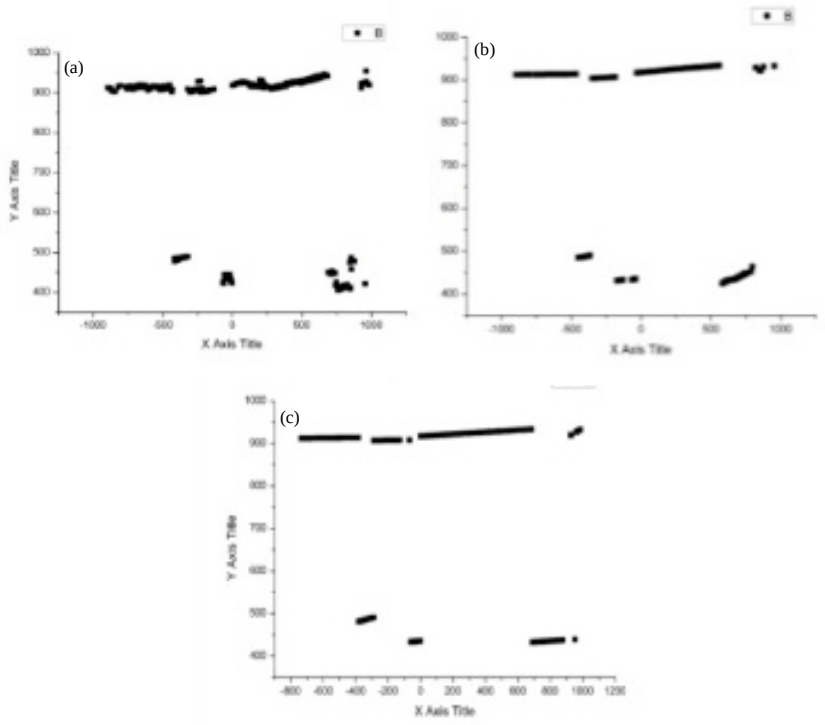

Fig. 1: Contrast figure of data processing. (a) Original data (b) After median filtering and (c) After median filtering and the least square method

According to the way of selecting odd number, median filtering that has a good function of noise filtering, especially white noise filtering, can eliminate the external noise of the entire data. In Least square method, the data of the basic data group are used for smoothing all the data of the gathered laser data, thus achieving the purpose of smoothing the data. This paper combines the two methods to make noise with the minimal impact on parking space detection.

PARKING SPACES DETECTING

Grid-based clustering methods: Indirectly acquire parking space information through obstacle information transition that is the main method to identify parking space. The basic step of parking space detection is shown in Fig. 2.

The parking space detection is the core of the system and is one of the core content of this paper. The parking space detection is depending on the obstacle detection. The environmental information around the vehicle is acquired by analyzing the detected obstacles and then calculating the empty parking space in the parking lot. Vehicle ECU evolves path planning by the information of empty parking space, so that automatic parking can be successfully precisely completed. This paper applies the grid-based clustering method.

This study also combines the least square method and median filtering to achieve data preprocessing before grid calibration. The corresponding data should be projected to the grid after data preprocessing. Since the grid is rectangular that has a certain proportion of aspect ratio, there are obstacles on the physical address of the grid when the laser data points projected in the grid reaches a certain threshold, otherwise there are not obstacles. In order to distinguish the obstacles and empty parking spaces in the grid map and find the corresponding parking space, statistic data and data clustering must be used to these grids, when all the data points have been projected in the corresponding grid.

This study chose grid-based method to data clustering in grid-based map creation. Grid-based clustering methods mainly include tree mesh and p*p mesh based on Cartesian coordinates. This paper chose the latter to achieve map display. According to the laser detection accuracy and the environmental requirements of automatic parking, this paper considers the surrounding 10×10 m area as region of interest. If the detected data reaches beyond 10 m, the corresponding data will be filtered or zeroed. The data within 10 m remains unchanged. The 10×10 area are divided into 100×100 grids, so the size of each grid represents the area of 10×10 mm.

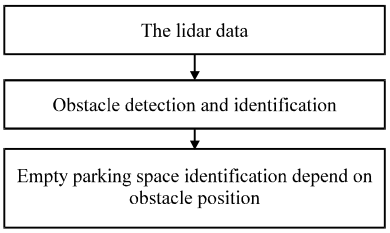

Fig. 2: Parking space detection process

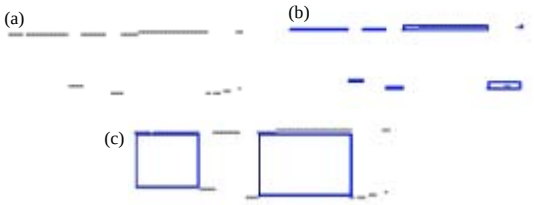

Fig. 3: Data display based on the grid. (a) Data display after data processing; (b) Obstacle display and (c) Parking space display

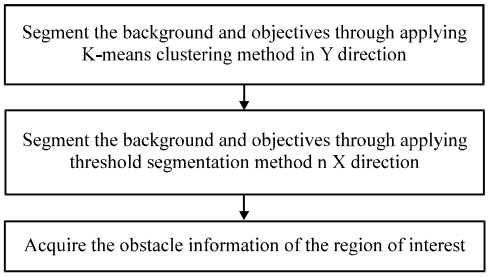

Fig. 4: Obstacle detection process based on K-means clustering and threshold segmentation

Based on this laser data processing program, the detected data are processed to the corresponding results, as shown in Fig. 3:

K-means clustering methods combined with threshold segmentation: K-means clustering method combined with threshold segmentation were used for obstacle detection. The basic step is shown in Fig. 4.

K-means clustering methods: The step of K-means clustering methods is shown in Fig. 5.

Set dataset for $\{[x_i], i = 1, 2, ..., n\}$

K1 [Initialization]: k data points $\{c_1, c_2, ..., c_k\}$ of dataset $\{[x_i], i = 1, 2, ..., n\}$ are selected as initial cluster centers.

K2 [Assign x_i]: Calculating the distance d_{ij}, $j = 1, 2, ..., k$ from $\{[x_i], i = 1, 2, ..., n\}$ to each initial cluster center $\{c_1, c_2, ..., c_k\}$, the data x_i are classified into the nearest class.

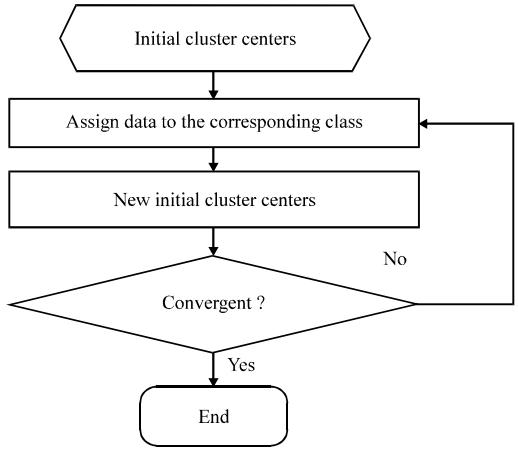

Fig. 5: Flow chart based on the k-means clustering

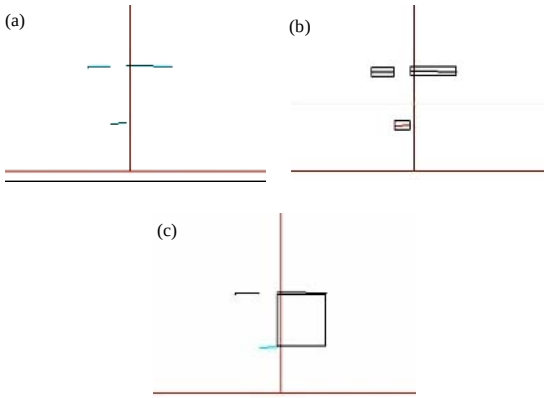

Fig. 6: Data display based on K-means clustering and threshold segmentation

K3 [Revise c_i]: The new class cluster center of each class is acquired through calculating the average of all the data in each class.

K4 [Deviation calculation]:

$$D = \sum_{i=1}^{n}\left[\min_{\gamma=1,2,\ldots,k} d(x_\gamma, c_\gamma)^2\right]$$

K5 [Whether the D is convergent]: If D is convergent, entire algorithm is end. Otherwise, return to K2 until D is convergent.

Threshold segmentation: Threshold segmentation is widely used in the data segmentation, especially common in the gray image to segment background and objectives. In image segmentation, an ideal threshold used for determining whether the pixel belongs to background or objectives, is selected based on the gray value difference between background and objectives. Since the threshold segmentation is based on a specific threshold to divide the image pixel, it is a good method to address the situation that the gray value difference between background and objectives is large.

The step of threshold segmentation:

- **Step 1:** Treat all objects in one class as a whole and the initial element of the class as basic point. Namely there also are two class, objective and background in the beginning of threshold segmentation
- **Step 2:** Calculate $d_{i+1} = |x_i - x_{i+1}|$
- **Step 3:** If $d_{i+1}<D$, x_{i+1} is belongs to the former class, then repeat step2 and calculate d_{i+2}; If $d_{i+1}>=D$, x_{i+1} is not belongs to the former class, so it need to set a new class, which treat x_{i+1} as the new basic point and return to step2 to calculate d_{i+2} and so on
- **Step 4:** Calculate the elements of all arrays. Threshold segmentation is end

Figure 6 shows the results based on K-means clustering and threshold segmentation. The blue line in Fig. 6a shows the laser data information after preprocessing. The rectangle in Fig. 6b shows the detected obstacles front of the vehicle. The rectangle in Fig. 6c shows the feasible parking spaces.

EXPERIMENT AND ANALYSIS

This paper use only miniature vehicle for this parking spaces detection experiment, the threshold of parking space is 3 m long and 2 m wide. LMS211 laser scanning measurement system is applied to detect the environment around the vehicle. Set scan angle for 100° and angular resolution for 0.5°. Each laser data group includes 201 data points and laser data unit defaults to centimeters. The information of data points includes x, y coordinate value and the Euler distance of obstacle.

The feasible parking spaces detection through experimental platform: This experiment has detected six group feasible parking spaces. If the distance between each cluster reaches the threshold, the platform shows the feasible parking spaces and displays the coordinates of the feasible parking spaces, as shown in Fig. 7.

According to the experimental results, this paper lists the six group parking spaces information and makes the analysis of statistical error. So the deviation from the parking spaces information of each group to the actual parking spaces information can be calculated and then the corresponding variance information can be calculated

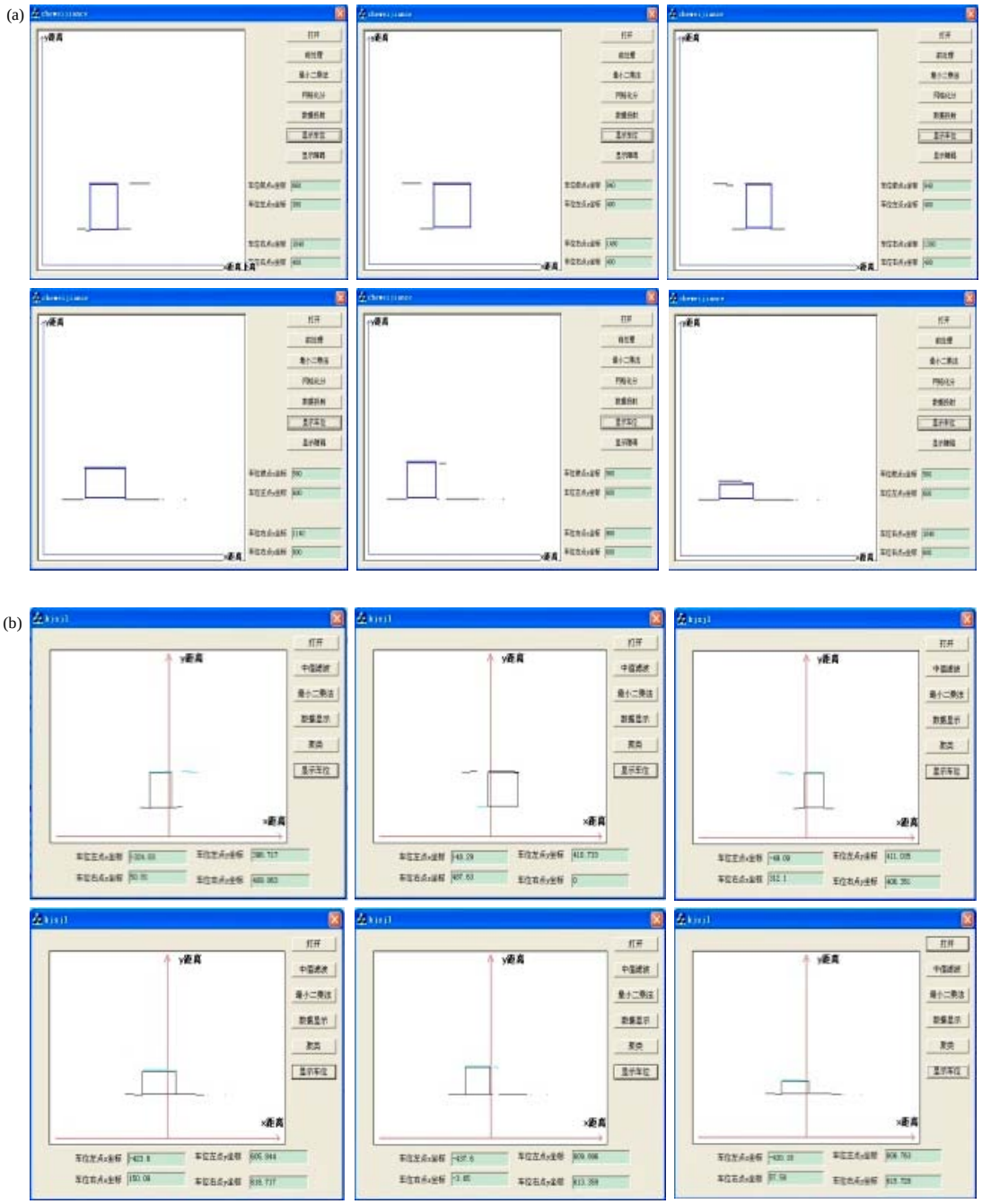

Fig. 7: The results of two algorithms (a) Parking spaces detection based on grid and (b) Parking spaces detection based on K-means clustering and threshold segmentation

based on the deviation. The stability of two methods can be acquired. As shown in Table 1.

The accuracy of parking spaces detection based on grid mainly depends on the defined size of the grid, the larger the size of the grid, the lower the accuracy and vice versa. The parking spaces detection methods based on K-means clustering and threshold segmentation does not change too much raw data, so it has higher accuracy compared with parking spaces detection method based on grid. The latter is more simple process of data processing compared with the former, so the latter has certain advantages on computational speed.

Table 1: Variance for two kinds of algorithms

Algorithms	1	2	3	4	5	6	Variance
Based on grid	-9.77	10.43	4.35	-9.75	-10.28	-5.87	8.74 cm
Based on K-means clustering and threshold segmentation	5.41	6.35	5.54	2.84	3.67	1.89	4.57 cm

Although the accuracy of the two methods differs, both of them can satisfy the requirement that detecting feasible parking spaces.

CONCLUSION

This paper devote oneself to development the environmental perception system of automatic parking based on the experimental platform of intelligent vehicle research group and the requirements of modern automotive technology. The data information of obstacles front of the vehicle, such as vehicle, wall, pedestrian etc. were acquired through laser rangefinder and then the program analyzed the feasible parking spaces. Firstly, this paper filter out the data noise through preprocessing method based on median filtering and least squares method and then detect feasible parking spaces based on grid and K-means clustering combined with threshold segmentation. Finally, this paper made a statistical analysis of the error size for the two methods and research their advantages and disadvantages. Experimental results show that this method has high robustness. Additionally, this paper has limitations that currently only pointing at vertical parking of miniature vehicle, so the research of parallel parking is still to be improved. And the dynamic characteristics obstacles will be considered in the future research to across-the-aboard intensive study the key technology of automatic parking system.

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