The Algorithm for Unstructured Road to Abstract Road Surface based on Color Feature

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Abstract—**Visual navigation of mobile robots is an important issue in the field of computer vision research. For the characteristics of unstructured roads, in this paper, we use color feature and space information to solve this problem. First, compress color space of color image containing unstructured road to quantity color values. Second, automatically select the appropriate growing seed point by the space distribution of road area in the color images containing road, and then progress regional growth and obtain the boundary of unstructured road. The experiments show that this algorithm could identify a wide range of unstructured roads base on only part of the image color characteristics. Further more, its accurate recognition results and a small amount of computation could basically meet the real-time requirement of the mobile robot during outdoor industry.**

Keywords- Unstructured-Road; identification; Regional growth

I. INTRODUCTION

In the several years, the autonomous navigation of mobile robot has attracted increasing attention in computer vision field. In structured-road environment, smart vehicles have been able to complete the autonomous navigation with the help of road sign, such as lane. However, in the natural environment, for the environmental diversity, randomness and complexity, intelligent robot navigation with real-time and adaptability has not yet been fully resolved, and have become a strategic research objective [1] in high-tech fields for many countries.

Unstructured-road identification for the intelligent robot plays an important role in improving the adaptivity and safety-driving ability under the circumstance of unknown and complex situation. At present, the road-extraction algorithm is divided into boundary-based segmentation [2], characteristic-based segmentation on color histogram [3] and characteristic-based segmentation on texture [4]. The most important problem of the characteristic-based segmentation on color histogram is that the importance of spatial information is often overlooked, which results to the road area is not continuous, so it is difficult to have practical values; the main problem of the characteristic-based segmentation on texture is the high computational complexity, which is difficult to meet the real-time requirement for the intelligent vehicle, and also very sensitive to the changes in image resolution.

On the problem of unstructured-road identification, we propose a region-growing and road-extraction algorithm based on color feature information. The algorithm extracts the road region in the current image, which uses the image's color characteristics and spatial information through the automatic seed point selection.

II. ROAD-IDENTIFICATION ALGORITHM

A. Color-space Selection

There are RGB, YCbCr, HSV, CMY, CMYK etc. [5] in the space of color image. In this paper the main problem is the analog of the human eye to complete the identification of unstructured road surface. Therefore in order to find color space close to the human eye, we propose that color images containing unstructured road surface information should be extracted for part road surface(Figure 1), and converted to a different color space (RGB, HSV, YCbCr), shown in Figure 2.
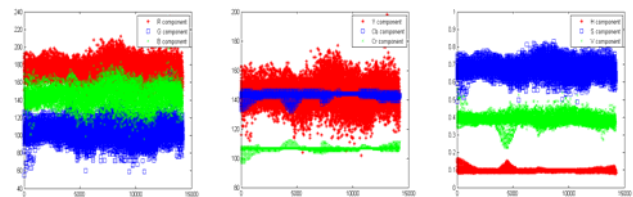

Figure 1. The part of pavement abstraction

Figure 2. The distribution of each component in RGB, YCbCr and HSV space

From the perspective of human eye, the observation point in the road can also be seen as the same or similar color, though they don't have all the same values. So the color space which has the highest concentration of the distribution point in the road is the space which is closest to the human eye. Figure 2 shows that the distribution of the extracted roads in the HSV

color space is relatively concentrated, so we convert all experimental images into HSV color space.

B. Color-space Compression

In 1978, founded by Ray Smith, Elway, the HSV model is a nonlinear transformation of the mode of the three primary colors of light. The color of this model is described more intuitive than the RGB mode, which can reduce the complexity of the color image and speed up the image processing. The relationship of the transformation is shown in the formula (1).

$$H = \arctan\left(\frac{\sqrt{3}(G-B)}{(R-G)-(R-B)}\right)$$
$$S = 1 - \frac{\min(R,G,B)}{3} \tag{1}$$
$$I = \frac{(R+G+B)}{3}$$

The model of HSV color space corresponds to a conical subset of the cylindrical coordinate system. It means the top face of the cone while V = 1. In the formula(1), H refers to the hue, that is the basic property of the color; S, the saturation, that is the purity of the color, which has value of 0-100%; V refers to the value.

In order to make the effect of color quantization closer to the real image, we introduce two steps of quantification to weaken the discontinuity of color quantization. The steps are as follows:

1) Using equation the formula (2) to quantify the three-component of H, S, V by nonlinear conversion: H component is quantified with 16-level,called H_1, S and V components are both with four-level to quantify, called S_1, V_1.

$$H_1 = \begin{cases} 0, [0°,15°]or(345,360] \\ 1, (15°,25°] \\ 2, (25°,45°] \\ 3, (45°,55°] \\ 4, (55°,80°] \\ 5, (80°,108°] \\ 6, (108°,140°] \\ 7, (140°,165°] \\ 8, (165°,190°] \\ 9, (190°,220°] \\ 10, (220°,255°] \\ 11, (255°,275°] \\ 12, (275°,290°] \\ 13, (290°,316°] \\ 14, (316°,330°] \\ 15, (330°,345°] \end{cases}$$

$$S_1 = \begin{cases} 0, (0,0.15] \\ 1, (0.15,0.4] \\ 2, (0.4,0.75] \\ 3, (0.75,1] \end{cases} \qquad V_1 = \begin{cases} 0, (0,0.15] \\ 1, (0.15,0.4] \\ 2, (0.4,0.75] \\ 3, (0.75,1] \end{cases} \tag{2}$$

2) Using the formula (3) to quantify the three-component of H, S, V by nonlinear conversion with the above agreement, and get H_2, S_2, V_2.

$$H_2 = \begin{cases} 0, [0°,20°]or(335,360] \\ 1, (20°,30°] \\ 2, (30°,50°] \\ 3, (50°,60°] \\ 4, (60°,85°] \\ 5, (85°,113°] \\ 6, (113°,145°] \\ 7, (145°,170°] \\ 8, (170°,195°] \\ 9, (195°,225°] \\ 10, (225°,260°] \\ 11, (260°,280°] \\ 12, (280°,295°] \\ 13, (295°,331°] \\ 14, (331°,335°] \\ 15, (335°,350°] \end{cases}$$

$$S_2 = \begin{cases} 0, (0,0.15] \\ 1, (0.15,0.4] \\ 2, (0.4,0.75] \\ 3, (0.75,1] \end{cases} \qquad V_2 = \begin{cases} 0, (0,0.15] \\ 1, (0.15,0.4] \\ 2, (0.4,0.75] \\ 3, (0.75,1] \end{cases} \tag{3}$$

3) Get average the results obtained in the above two steps: H ', S', V '. H '= (H1 + H2) / 2, S' and V 'remains unchanged.

4) According to equation (4), integrate H ', S', V ' to a matrix L, and all its elements are the values of 0 to 255. QS and QV is respectively the quantify progression of S, V component.
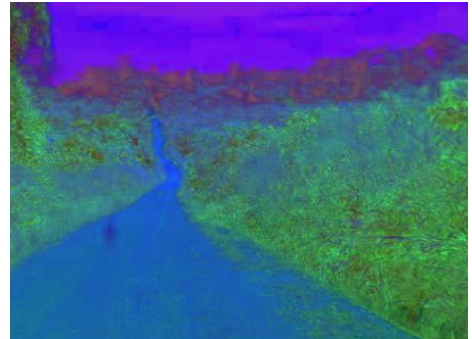
$$L=H'*QS*QV+S'*QV+V' \tag{4}$$

Figure 3. The translation in HSV color space

Figure 4. Color quantification

C. The regional growth algorithm for road surface abstraction

While intelligent vehicles travel in an unknown environment, the biggest problem facing to is the uncertainty and environment complexity of around. First of all, because of the diversity of unstructured roads, a variety of road will appear, such as sand road, cement road; Secondly, due to the impact of view point and sensor direction in data acquisition and other factors, the images intelligent vehicle collect always contain roads with diversity shape, such as trapezoidal, S-shaped, accordingly the traditional methods based on a single model is feeble for the identification of unstructured roads. In addition, due to the indeterminacy and diversity of pavement, so the road surface texture information is the supporting role in intelligent vehicle navigation. Therefore, this article focuses on solving unstructured road location and extraction of the size of road area.

This paper identifies the road from the perspective of the human eyes, and assumes that the current vehicle is traveling on the road. Though the B method, the color images are converted to the expression in HSV color space and quantify its color values, and then the region growing algorithm is applied to obtain the seed point automatically [7].In this way pavement area the color images contains is acquired.

1) The initialization of seed node

To region growing algorithm, the sticking point is the selection of the seed node and regional growth rules [8]. Since we have make assumptions that intelligent vehicles be traveling on the road, it can get conclusion that just below the images collected by the smart vehicle there is a large number of road information. Therefore, the last line of data points in the experimental image could be the basis of seed nodes selection, and they are called as Seeds. The distribution of Seeds in figure 3 after color quantization is shown as figure 4.
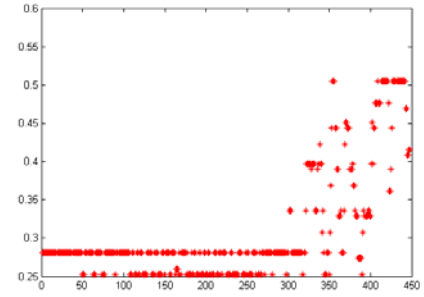

Figure 5. The distribution map of Seeds

According to the analysis of figure 6 to figure 5, we can see that the most concentrated part in the map of the Seeds (0.2526 ~ 0.2815) corresponds to the road surface portion of original image, while the part scattered and right side of figure 8 corresponds to the fuzzy boundary of the road. As a result, the conclusion can be drawn: the section that most concentrated in Seeds distribution map correspond to the value of road.

Integrating the above assumptions, the center of the bottom of experimental images is selected as a seed point coordinates, and the average value of Seeds is taken as the initial value of seed node .

2) Regional Growth Rules

After initializing the seed node, the seed node would grow pavement region in accordance with the designated regional growth rules. Eight points in the neighborhood of all selected nodes is searched by this way in order to get continuous growth area. The process is as follows:

a) Initialize the seed node Seed, and add the node to the collection of S.

b) Find the nodes in collection of Seed of eight points in the neighborhood n , according with the condition $|V_{Seed} - V_n| <$ Threshold, and add them to the collection of S. Here the variable V_{Seed} is the average of the growing point value, V_n is one of the values in currently growing parts of the eight points in the neighborhood, and Threshold is the threshold when add a new growing node in the growing region . A large number of experiments shows that this threshold value always fluctuate from 0.05 to 0.15. For little effect of its selection on extraction efficiency on the road, here take it the 0.06.

c) If all the eight neighborhood points of growing point do not meet the conditions in step 2, then exit region growing; otherwise, put the new point in the set S complying with the rules of the new point growth, and repeat step 2 until no eligible new point appears.

3) Extraction algorithm of unstructured road based on color feature

Of the road extraction algorithm used is as follows:

a) Translate all experimental color images to HSV space.

b) To H, S, V three components, use the method as B described for color quantization separately, and then integrate the three components to generate the grayscale image of compressed color space.

c) Select the initial seed node called Seed; determine the initial growth position and the initial value.

d) Grow road region according to the selected area growing rules until there is no new growth point to join.

III. RESULTS

The selected road images in experiment are a part of search results in Google image site. In order to maximize the consistency between the experiment data and the data of intelligent vehicle collected, the experimental color images are all converted into images with the same size of 448 * 336. The experimental results are shown in figure6~8.

Figure 6. Original images

Figure 7. Abstraction of pavement

Figure 8. The boundary of road

The experiments select several color images containing variety of terrain and pavement shape to test the algorithm. The experimental results are shown as above. We can see that, the algorithm can accurately detect the road area included in color images, and the road boundary is in line with the actual situation. Among them, although there is a lot of shadow in the third image of the road, the algorithm still detects the location and extent of the road with some visible spot. It shows that the ability of the algorithm to adapt shadow is still weak, and its improvement is to become the next focus of the future study. In addition, in order to test the efficiency of the algorithm, the experiment takes 10 cycles experiment separately on the Figure 9 of the original figures. The average running time is 4.78

seconds, 6.73 seconds, 3.27 seconds. The experiments show that the implement-efficiency of the algorithm is preeminence and could meet requirements of real-time data processing during the autonomous navigation of intelligent vehicles.

IV. CONCLUSION

In order to solve the problem of autonomous navigation of intelligent vehicles in complex unknown environments, this paper studied the issue from the point of view that how to identify the surface of unstructured roads. By making full use of color and spatial information in the image, color space compression and automatic region growing are introduced in road-surface identification. The experimental results are satisfactory, and could meet the requirements of real-time characteristic in intelligent navigation at complex environments, and there are another road recognition method is supplied to road identification.

However, due to the diversity of complex environments, the algorithm should fuse other features, such as texture feature, spectrum distribution feature and so on, in order to have the ability to adapt to the shadows, illumination changes. In addition, the study of the selection method of threshold value in region growing is still the focus of future research. To sum up, for the future research work more comprehensive features information will be combined together on the identification of unstructured road pavement to improve robustness of the algorithm.

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