Road Detection Based on the Color Space and Cluster Connecting

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Abstract—This paper propose a road detection, which is based on the color space and cluster connection. Generally, this method consists of two steps. The first step is road detection based on the color space. The second step is removing the fails road detection in the first step by using correlation. The correlation formula is used for calculating the similarity of each cluster image. The fails road detection will be removed, if their cluster image uncorrelated with neighbors cluster image. The simulation results show that our method has good performance which is capable significantly removing fails road detection. As well as evaluation by using precision, recall and accuracy have been presented.

Keywords—road detection; color space; image cluster

I. INTRODUCTION

Currently, the automatic control technology has been implemented to various fields of science, such as industrial, robotics, automotive and others. In the field of automatic control automotive is used for Autonomous Guided Vehicles (AGV). In the AGV, the road can be found by analyzing an image which is obtained by a camera.

Road detection is one of the part of environment understanding for intelligent vehicles. Many methods that have been developed to obtain a good result for road detection. That system involves many kinds of sensors like radar, camera; many different features like texture features [1], [2], and spatial feature [3]; and different algorithms like optical flow [4], or neural networks [5].

Generally, detection road with line mark is commonly used in AVG. However, many unmarked roads in rural areas and inner-city, to solve that problems a number of publications have proposed road detection algorithms that ignores lane marking detection. The extraction road being flat has been used in a variety of approaches [6]. A multilayer laser scanner is used for road estimation on rural road [7].

Another approaches put higher emphasis on appearance cues such as the color and texture of the road area [8], [9], [10], [11]. These visual properties of the road have been widely used for estimating road shape and segmenting the road area [8], [9], [10].

A road image can be classified into two, there are structured and unstructured road images. Structured road image can be seen on a road in unburn area, while unstructured road can be seen in rural area. Hough transform, steerable filters and Spline model have been generally used to detect the road boundaries or markings [11]-[13]. However, they only work well for structured roads which have road markings or borders.

Unfortunately, the road detection based on the color sometimes produce fail detection when the non-road has the same color with the road. We solve that problem by clustering the image. We eliminates the non-road detection that have no connection with the other clusters.

II. PROPOSED METHOD

In this study, we propose a road detection methods which based on similarity of road color space and cluster connection. Fig. 1 shows the road detection system of proposed method. The color space is generated from data set. Data sets are consist of sample color of road which is obtained from the image that will be passed by a vehicle. We use correlation formula for calculating the cluster similarity. The correlation is also used for analyzing the connection between clusters.

A. Color Space

We use the data set as a data reference in determining whether a road or no road. The data sets are obtained manually from generally a road and then we symbolized by $D_s$. 

Figure 1. Road detection system.
If the data set is symbolized by D then we can forecast a road object in an image through the color space of D. Color space of D is obtained by Eq. (1).

\[ C_{RGB} = \min(D_{RGB}) : \max(D_{RGB}) \]  

(1)

\( C_{RGB} \) is a color space and we provide three groups for the color space there are color space for red (R), green (G) and Blue (B) that is symbolized by \( C_R \), \( C_G \) and \( C_B \).

Equation (1) expressed the degradation of color start from the minimum pixel value (\( \min(D_{RGB}) \)) up to the maximum pixel value (\( \max(D_{RGB}) \)). So that, \( C_{RGB} \) will produce linear data pixel value.

Fig. 3 (a) and (b) are data set for general road and typical road. Figure 3 (c) and (d) are R, G and B color for data set image in Fig.3 (a) and 3 (b). RGB color on Figs. 3.c and d are mapped in RGB color space as shown in Figs. 3.(e) and (f). The color space for data set is marked by white box as shown in Fig. 3(e) and (f).

**B. Road Detection**

We detected the road by comparing each element of the image \( F \) with the color space. The color space is generated from data set. If the color of elements of an image \( F \) are in the range of the color space, then the coordinate will be marked as a road, and vice versa.

\[ R = \begin{cases} 
1 & \text{if } F_R \in C_R \text{ or } F_G \in C_G \text{ or } F_B \in C_B \\
0 & \text{others} 
\end{cases} \]  

(2)

\( R \) in Eq.(2) is labeling image of road, “1” is road indication and “0” is non road. \( F_R \), \( F_G \) and \( F_B \) are input image for R, G and B images respectively. \( C_R \), \( C_G \) and \( C_B \) are data set image.

**C. Clustering**

Clustering is to divide an image into several smaller parts. The smaller parts of image or image cluster will be analyzed and compared with the neighbor cluster. Fig. 4 shows the clustering of road image. We will analyze each cluster by correlation. Fig. 5 shows the observation of neighbor image cluster [14], [15]. The green color is the current cluster position of the image. The current cluster position will be calculated the correlation value with neighbor clusters. We use nine possibility of image cluster that indicated the road, as shown in Fig 5.(a) up to (i).
D. Correlation

Correlation evaluation is used to measure the power of two variables. Two variables are referring image cluster and another one of neighbor image cluster. The power of two variables is expressed by a values between 0 up to 1. If the value of the correlation is close to 1, then the cluster image is similar with cluster image reference and vice versa.

\[ r = \frac{\sum_{y=1}^{M} \sum_{x=1}^{N} (f(x,y) - \bar{f})(f_T(x,y) - \bar{f}_T)}{\sqrt{AB}} \]  \hspace{1cm} (3)

\[ A = \sum_{y=1}^{M} \sum_{x=1}^{N} (f(x,y) - \bar{f}) \]  \hspace{1cm} (4)

\[ B = \sum_{y=1}^{M} \sum_{x=1}^{N} (f_T(x,y) - \bar{f}_T) \]  \hspace{1cm} (5)

wherein, \( \bar{f} \) and \( \bar{f}_T \) are equal to the mean value of \( f(x,y) \) and \( f_T(x,y) \). In this case \( f(x,y) \) is a cluster in image \( F \) and \( f_T(x,y) \) is neighbor cluster of \( f(x,y) \).

\( r \) is the correlation value between the current cluster and neighbor cluster. We calculate the correlation value start from top-left cluster and move to right cluster, and then it is continued for an existing cluster on the next row until the end of cluster at the right bottom.

During the scanning process of the correlation calculation, we are directly analyzing the correlation value of neighbor clusters. The gray color in Fig. 5 indicates that the image clusters have correlation value close to current image cluster. If the correlation values have a position like one of configuration in Fig 5(a) up to (i) then the current cluster is indicated the road.

After we know the current position of image cluster is indicating a road, then we are directly checking the same cluster position in the road detection image following the cluster map condition as shown in Fig 5. If the detection of the road does not meet the conditions as shown in Fig 5. We eliminate detection of the road in the same cluster position.

III. EXPERIMENTAL RESULT

In this section, we test the performance of our method. Meanwhile, to study the performance of our proposed method, we compare it with other method such as template matching.

A. Qualitative Evaluation

Qualitative refers to descriptions or distinctions based on some quality by human visual observation [16]. We use two structured images and two unstructured images for testing as shown in Fig. 6.(a), (b) and Fig.7.(a), (b). Figures 6. (c) – (d) and Fig. 7. (c)-(d) show the simulation result by using template matching (TM). The performance of proposed methods are shown in Fig. 6.(e)-(f) and Fig.7(e)-(f).

Visually, template matching method is resulting fail road detection. This is caused the template that was used matching with the non-road. There are many non-road colors which are similar with the road template. The road detection is shown by green color. Figures 6.(c)-(d) show the green color at outside of the road, the same with road detection results in Fig. 7.(c)-(d).

The proposed method shows better than template matching (TM) method. The proposed method capable to reduce fail road detection, as shown in Fig. 6.(e)-(f) and Fig.7.(e)-(f).
B. Quantitative Evaluation

Qualitative evaluation by human visual is more subjective compared with the quantitative evaluation, where it can be observed but not measured. In this paper, we use four evaluation methods such as Precision, Recall, F-measure and accuracy as shown in Eq. (6) up to (9). These methods are generally used for image analysis [17]-[20].

\[
\text{Precision} = \frac{TP}{TP + FP} \tag{6}
\]

\[
\text{Recall} = \frac{TP}{TP + FN} \tag{7}
\]

\[
F - \text{measure} = \frac{(1 + \beta^2) \cdot \text{Precision} \cdot \text{Recall}}{\beta^2 \cdot \text{Precision} + \text{Recall}} \tag{8}
\]

\[
\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \tag{9}
\]

In this evaluation, we use two images. The evaluation results by using Precision, Recall, F-measure and Accuracy are shown in Table I and Table II.

Table I is evaluation result of image in Fig. 6.(a). The evaluation value of proposed method is greater than Template Matching (TM) method. For evaluation by using Recall, F-measure and Accuracy, our method is slightly higher than template matching. Our method is more precision compare with TM.

Table II shows the result of Precision, Recall, F-measure and Accuracy for image in Fig 7.(a). The precision value of proposed method is more higher than template matching (TM) method. This is caused by many fail road detections of TM method.

<table>
<thead>
<tr>
<th>TABLE I.</th>
<th>EVALUATION RESULT FOR IMAGE IN FIG.5.(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Precision</td>
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<tr>
<td>TM</td>
<td>90.5</td>
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<td>Proposed</td>
<td>94.3</td>
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<table>
<thead>
<tr>
<th>TABLE II.</th>
<th>EVALUATION RESULT FOR TYPICAL IMAGE IN FIG.6.(A)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Precision</td>
</tr>
<tr>
<td>TM</td>
<td>55.5</td>
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<tr>
<td>Proposed</td>
<td>80.7</td>
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</tbody>
</table>

IV. CONCLUSION AND FUTURE WORK

A. Conclusion

The road detection based on color space and cluster evaluation by using correlation have been presented. The color space is generated from data set of general road. The range of color space is start from the minimum until the maximum values of data set. The road can be obtained by comparing the color of image with the color space. We reduce fail road detection by clustering correlation observation. Our method have been tested on structured and unstructured road images. The proposed method has been evaluated by using Precision, Recall, F-measure and accuracy. The evaluation result shows that the proposed method is better than template matching.

B. Future Work

For next research, we will continuing and improving our method for real time road detection. The next method will be implemented for guiding mini electric car.

REFERENCES


