Lane Detection using Fuzzy C-Means Clustering

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Abstract

In general, road lane detection from a traffic surveillance camera is done by the analysis of geometric shapes of the road. Thus, Hough transform or B-snake technology is preferred to intelligent pattern matching or machine learning such as neural network. However, we insist that the feasibility of using intelligent technique in this area is quite undervalued. In this paper, we first divide the image into halves and use only the lower part in detection and binarize them by analyzing RGB channel. Then the boundary lines are extracted by applying 4-directional contour tracking algorithm and vectors with distance and angle values are extracted from those boundary lines to use as input for fuzzy C-means clustering algorithm. Clustered vectors form a straight line for road lanes by our method. In experiment, the proposed intelligent method is slightly slower than Hough transform but better in accuracy thus there is a room for intelligent method such as fuzzy C-means to solve this problem.

Keywords: *RGB channel, 4-directional contour tracking algorithm, Fuzzy C-means, Rroad lanes*

1. Introduction

One of the frequent applications of image processing is ITS (Intelligent Transport System) using CC-TV [1]. One of the basic but important algorithms in such image analysis is lane detection. It is a basic building block of many traffic analysis applications such as lane change detection and collision detection. There has been a great deal of research into lane detection for operating intelligent vehicles. Hough transform that maps a line as an intersection point in the Hough area if it is translated to a coordinate system that has the relative rotation angle and distance from origin, i.e. the polar coordinate [2] and B-Snake technology [3] are two well known algorithms in this department. However, one may argue that these algorithms are basically based on the linear processing schemes. Recent trend in computing paradigm is to use MIMD with parallel processing in order to obtain maximum utility of resources such as cloud systems as an example.

From that point of view, we argue that a system based on artificial intelligence such as fuzzy logic or neural network might be more efficient than linear systems in such environment even in low level ITS applications [4]. Such intelligent techniques have been mostly disregarded in problems such as lane detection since Hough transform or B-snake simply looks more efficient in linear processing environment.

2. Lane Detection using Fuzzy C-Means Clustering

We use 640 x 480 size 24 bit BMP format images as input. We first divide the image into halves and use only the lower part in detection and binarize them by analyzing RGB channel. The reason for using only lower half is that the upper part has only small portion of information about road lane thus it is inefficient considering the processing time. Road lanes are typically white or yellow thus we binarize them as such. Then the boundary lines are extracted by applying 4-directional contour tracking algorithm and pixels having value less than 100 are removed as noise. Figure 1 summarizes these preprocessing steps.

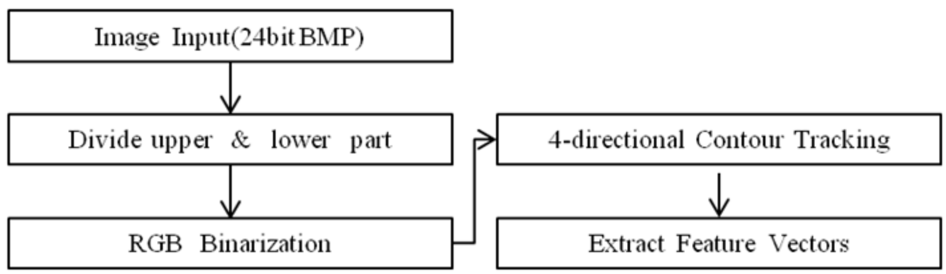

Figure 1. Image Preprocessing Steps

Input characteristic vectors are extracted by applying formula (1) having the distance and the angle for every 50 pixels.

$$V_i = \begin{cases} Dist_i(P_{k \bmod 50}, P_{k \bmod 50+50}) \\ Ang_i(P_{k \bmod 50}, P_{k \bmod 50+50}) \end{cases} \quad (1)$$

where P is the coordinates of boundary line. Figure 2 shows the vector extraction process.

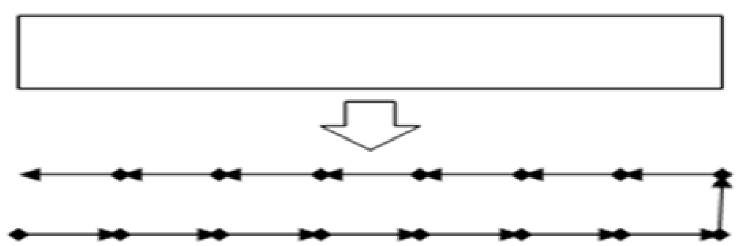

Figure 2. Feature Vector Extraction

FCM clustering [5, 6], originally designed in 1973 by Bezdek, is a classification algorithm that enumerates degrees of cluster membership for each data based on the distance from the center point. The membership degree is represented by a number between 0 and 1 and the cumulated sum of dataset is 1. In formula (2), U_{ik} denotes the membership degree of k^{th} data belongs to i^{th} cluster. The center of j^{th} cluster is computed by formula (3). Then the new membership degree $U_{ik}(r+1)$ is computed by formula (4). The procedure is repeated until the difference between the new and old membership degree is smaller than the threshold value and as a result, input vectors are clustered as such.

$$\sum_{i-1}^{c} U_{ik} = 1, \nabla k = 1, \cdots, n \tag{2}$$

$$v_{ij} = \frac{\sum_{k=1}^{n} (U_{ik})^m x_{kj}}{\sum_{k=1}^{n} (U_{ik})^m} \tag{3}$$

$$U_{ik}^{(r+1)} = \frac{1}{\sum_{j=1}^{c} \left(\frac{d_{ik}^{\ r}}{d_{jk}^{\ r}} \right)^{2/m-1}} \tag{4}$$

Figure 3 shows the plotting of input vector set into FCM.

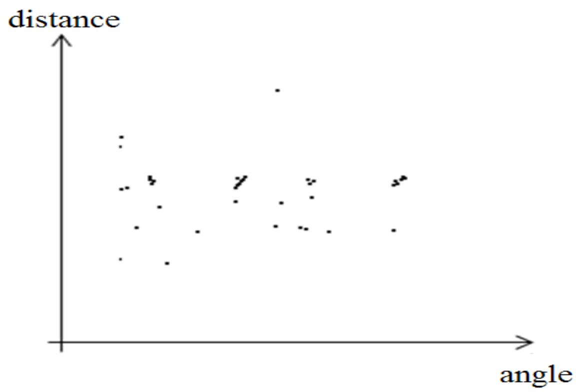

Figure 3. Vector Graph

Naturally, input vectors form a loosely coupled clusters as shown in Figure 3 since vectors from the same straight line(lane) have similar distance and angles. When we use FCM, we should provide the number of resultant clusters and it was 4 in this paper. Vectors are more clearly clustered after applying FCM as shown in Figure 4. Figure 5 shows the result of FCM comparing with the original image.

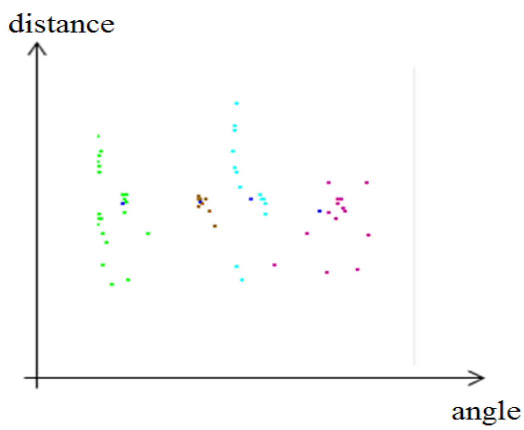

Figure 4. Clustering Result

The original image (Figure 5 (a)) is divided into two parts and the lower half is binarized (Figure 5 (b)) and 4-directional contour tracking algorithm is applied (Figure 5 (c)) and the characteristic vectors are extracted (Figure 5 (d)) and FCM is applied to them as shown in Figure 5 (e).

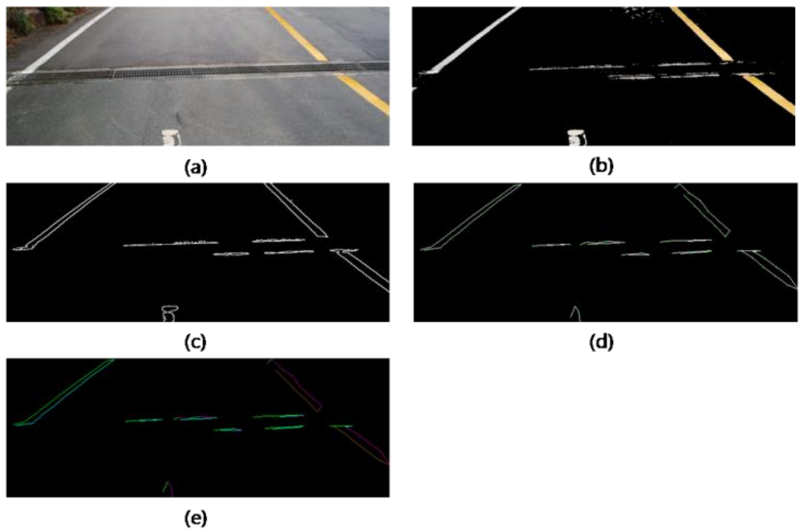

Figure 5. Original Image and Image after FCM

3. Experimental Results and Analysis

The software is written in Visual Studio 2005 on an IBM compatible PC with Intel Pentium-IV 3 GHz CPU and 1G RAM using images of 24 bit BMP format 640 x 480 in size.

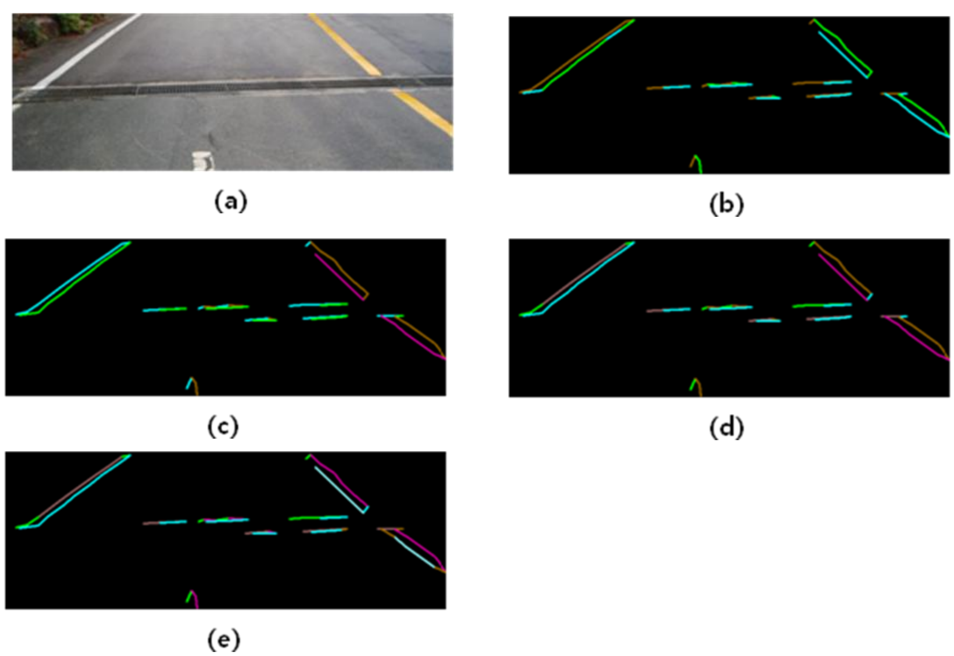

Figure 6. Experiment on the Number of Clusters

The main clustering algorithm FCM requires fixed initial number of clusters by nature. Although that is the main deficiency in this type of application, we use the number of clusters from 3 to 6 and compared them in Figure 6. Figure 6(b) has the number of cluster 3 and Figure 6 (c) has 4, Figure 6(d) has 5, and Figure 6(e) has 6.

As shown in Figure 6, presetting the number of clusters is not a big problem in this application but for most cases, the two center lines are most important thus FCM using 4 as the number of clusters is most efficient in our experiment.

4. Conclusions

The common conception of applying intelligent algorithms such as fuzzy logic or neural network is finding an application that is not too much speed-sensitive and has less formal information like geometric characteristics. However, its possibility of adopting parallel processing schemes is another advantage for extending its usability.

Our effort here using FCM in low-level ITS that has well deserved formal characteristics such as lane detection can only verify that the intelligent algorithm has been undervalued in such problems and it can be applied in real time as well if the environment allows (or requires) non-linear processing environment.

Simple characteristic vectors extracted by image preprocessing are successfully clustered into a straight line without losing lane information even with partly disconnected real world road lanes in our experiment. However, the current method can only be applied to straight lines and produces some amount of false positive objects and these problems will only stimulate us to develop the next research.

References

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