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HSI Color Model Based Lane-Marking Detection

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Abstract—**Lane-marking detection is one of the major concerned topics in the field of driving safety and intelligent vehicle. In this paper, a new method using HSI color model for lane-marking detection, HSILMD, is proposed. In HSILMD, full color images are converted into HSI color representation, within the region of interest (ROI) aiming to detect road surface on host vehicle, the difference of intensity distribution of a row of pixels within ROI is recorded and clustered with Fuzzy c-Means algorithm. Thresholds of intensity and saturation are selected accordingly. With simple thresholds and operations, lane markings on various road scene images are detected. Results are compared with the same scheme using RGB color model and a different scheme. Robustness of this reduced computation consumption system is observed**.

I. Introduction

LANE-marking detection is one of the major research topics which contributes to safety driving assistance systems and intelligent vehicles. The aim of lane-marking detection is to give information to on-board intelligent computing equipments as a major knowledge of driving environment. The knowledge helps the system to perform road following and lane-keeping in autonomous vehicle. As a driving assistance system, it is applied in avoiding inattentive lane departure by giving warnings to unaware drivers, offering a safe and comfort driving assistance. Analysis of the risks raised from avoiding obstacles and overtaking vehicles within the detect lane width could be carried out with precise lane detection, which in turn raises driving safety.

With up-to-date technologies, various methods and techniques are proposed in order to perceive lane information. Laser and radar sensors [1][2] are used to detect and track road boundaries with higher system costs. Another alternative is by using image sequences captured by digital camera/recorder for further analysis. Data obtained with digital eyes are friendly to human sight. However, computers deal with such images in a completely different way than human beings, which is the issue of computer vision. A comprehensive report [3] shows that by computer vision, an intelligent driving platform could be realized with vision in and out of vehicles. Taking advantages of using digital image raw data for observing driving environment, various transforms like Hough transform [4][5] and inverse perspective mapping (IPM) [6] are proposed. Color analysis is also a preferred scheme in lane-marking detection [7][8].

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In this study, we propose a method for lane-marking detection－HSILMD, which is carried out by color analysis of road scene images using hue-saturation-intensity (HSI) [9] color model. In HSI-based analysis, advantages of loose threshold yields good detection results are observed of using HSI model compared to RGB. This paper is organized as follows: in Sec.II, the overall system is introduced in detail. In Sec. III, we compare our work with the algorithm proposed in [8] and present organized experiment results of our algorithm and finally a conclusion is made in Sec. IV.

II. Proposed Method

A. Overview

Lane markings are characteristically in contrast to road surface on its color and intensity, which are used as important and preferred elements in analysis. Several color models are used to express color image, the most widely used are RGB, YCbCr, HSI and $L*a*b$ [10]. With the comparison of HSI and RGB model aimed to detect lane markings, saturation S and intensity I values in HSI model are adequate to carry out detection, hue H also gives information to the problem but not as significant as I and S. The advantages of choosing HSI color model is presented in part B below, the lane-marking detection system is described in part C and beyond.

B. Advantages of HSI color model in Lane Detection

In this study, effort is paid to study the advantage of using HSI color model in lane-marking detection with simple thresholds. From observing the color images of road scene in HIS model, the pixels of lane-marking have S and I value much higher than the pixels of road surface. However, hue H value varies just slightly in comparison. In RGB model, although pixels of road surface are in contrast to lane markings with obvious difference in RGB values, both R, G and B values are required to distinguish the two. HSI in turn saves computation consumption and raises efficiency of detection. Furthermore, due to different colors of lane markings appear on the road, multiple thresholds are required to avoid miss-detection. In the proposed method, lane markings of different colors are detected using HSI color model without miss-detection.

C. System Architecture

A compact overview of the proposed system is depicted in Fig. 1. The system is carried out as ordinary image analysis; road scene image sequence is captured from camera mounted on host vehicle, having similar perspective of the driver. A frame from the RGB image sequence captured is than converted into HSI-based image as preprocessing. A horizontal scan line shown as Fig. 2 is initialized on the 178^{th} row, which is to be above one-third of the height from the bottom of the image. To reduce computation consumption and to raise precision of detection, a ROI is defined from the bottom of the image to the vanishing point of the road approximately. As mentioned above, value of I tends to be the main cue in distinguishing lane-marking from road scene, so intensity value, I, of all the pixels lying on the scan line are recorded. As shown in Fig. 3, a histogram of intensity difference between two adjacent pixels (Eq. (1)) is drawn. For ease of reading, scale of I is normalized to the range $\{0...255\}$. Fuzzy c-Means clustering (FCM) [9] is applied aiding to divide pixels with lane-marking-like intensity threshold. Further stages of segmentation and filtering are followed to obtain final result.

$$I\_diff_j = | I_{ij} - I_{ij+1} |, \quad j = 1,...,w \ \ (w = width\ of\ image) \tag{1}$$

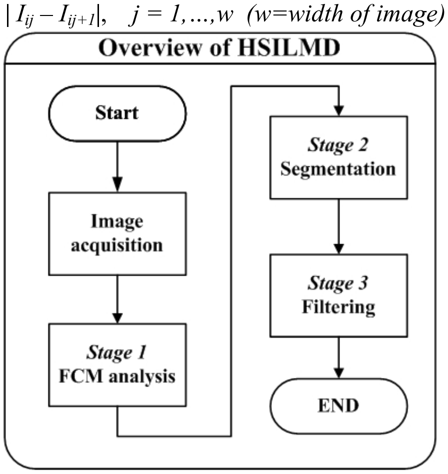


Fig. 1. System Overview.

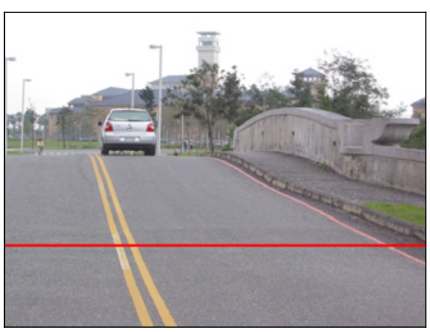


Fig. 2. Original traffic scene with scan line on row 178.

D. Fuzzy c-Means Intensity Difference Segmentation

It is easy for human to distinguish pixels with high difference compared to others in a sight of glance; however, it is not as strict to have classes separated in computing. Referring to our previous work [8], FCM algorithm is applied to perform the task. It was found experimentally that 15 iterations were satisfactory for FCM to achieve preliminary segmentation for lane-marking detection. FCM works well in segmenting I values of lane-markings from other road surface intensities, with clusters of low and high difference separated into I_1 and I_2 respectively (superimposed on Fig. 3.).

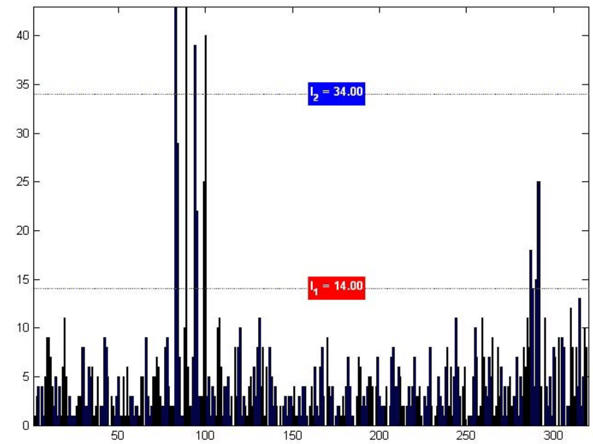


Fig. 3. Histogram of intensity difference of a row on an image of 320×240 .

E. Stage 2- Segmentation

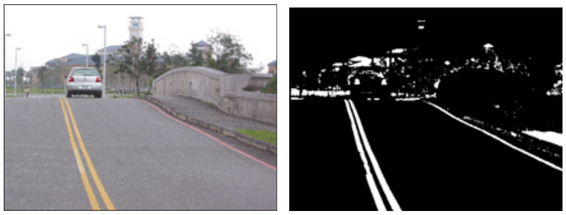
1) Intensity-only ($I_{th} - only$) segmentation

A simple threshold of intensity I_{th} is going to be obtained with the above clustering result. For right-forward driving direction in Taiwan, the right-hand-side lane-marking would be sometimes unavailable or unclear compared to the left-hand-side one, which is most likely the middle lane separation on a bi-directional lane. With respect to this condition, I_{th} is taken from the first pixel on the left which has intensity higher than I_2 , as shown in Fig. 4.

```
for j = 1 to width of image
    if ( I_ij ≥ I_2 )
        I_th = I_ij ,
        S_th = S_ij,
    end if
end for
```

Fig. 4. Pseudo code of recording intensity and saturation thresholds.

The segmented result using I_{th} is shown in Fig. 5.(b). Furthermore, saturation value S_{ij} of the pixel with I_{th} is also reserved for further usage as threshold S_{th} if necessary; the reason for this is going to be discussed. Segmentation using I_{th} raises satisfactory results in lane-marking detection. However, driving environment is rather complicated, and road scenes may not be as ordinary as the experiment image used in Fig. 2. Due to variations of weather, lighting of roads, e.g. tunnels and different road side lightings, in such cases using I_{th} may fail as the only constraint for filtering. By carrying out experiments of different road scenes, it is observed in Fig. 6.(c) that I_{th} alone is sometimes inadequate to perform appreciative detection.



(a) (b)

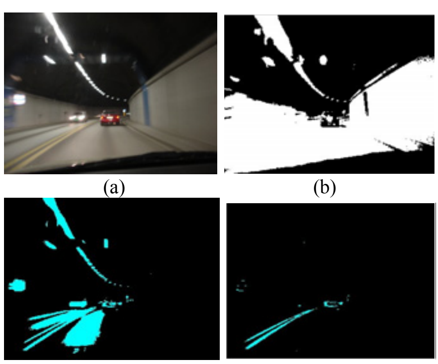
Fig. 5. (a) Original Image. (b) Segmented Image Using I_{th}.

2) Adaptive saturation-incorporated filtering $(I_{th}\ \&\ S_{th})$

As a solution to the above problem, another main cue in segmenting lane-marking is applied *S*, saturation of color. Incorporation of S_{th} along with $(I_{th}\ \&\ S_{th})$ is necessary to eliminate plenty pixels with intensity $I_{ij} \geq I_{th}$, but with different degree of saturation. Obvious advantage of $(I_{th}\ \&\ S_{th})$ is observed from Fig. 6.(d). However, applying S_{th} to every scene is not a suitable choice as observed in Fig. 7.(d), which occurs that some portion of lane-marking is miss-detected. With two thresholds, it is too critical for road surface with brightness in contrast to lane-marking;

Due to this condition, a mechanism is derived for determining whether S_{th} incorporation should be applied. The amount of pixels having intensity value $I_{ij} \geq I_{th}$ is counted as the degree (*S_necessity*) of necessity for *S* incorporation. If *S_necessity* is higher than a preset threshold, it tells that the intensity of road surface may be too close to I_{th}. In this case S_{th} is adaptively incorporated as the second threshold to effectively segmenting lane-markings, where I_{th} is still the elementary cue in the system.

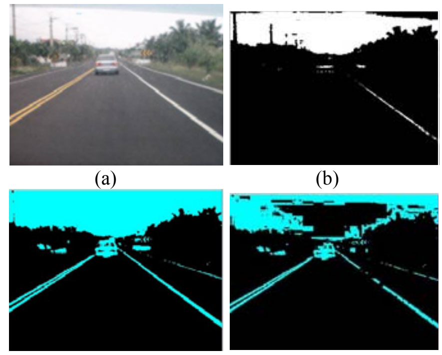
By experimental trial, the threshold for *S_necessity* is defined as 80 for which it suits most of experimental images. Pseudo code defining *S_necessity* is depicted in Fig. 8. A summary for stage 2 including adaptive mechanism for selecting $(I_{th} - only)$ and $(I_{th}\ \&\ S_{th})$ segmentation schemes is drawn in Fig. 9.



(a) (b)

(c) (d)

Fig. 6. (a) Original Image, (b) RGB threshold segmentation,
(c) Intensity-only segmentation, (d) Intensity and saturation segmentation.



(c) (d)

Fig. 7. (a) Original Image, (b) RGB threshold segmentation,
(c) Intensity-only segmentation, (d) Intensity and saturation segmentation.

// Adaptive segmentation selection
$S\_necessity = \sum (I_{ij} \geq I_{th})$
if $S\_necessity \geq 80$
  then apply $I_{th}\ \&\ S_{th}$ segmentation,
  else apply $I_{th} - only$ segmentation
end if

Fig. 8. Pseudo Code of Adaptive Segmentation Selection

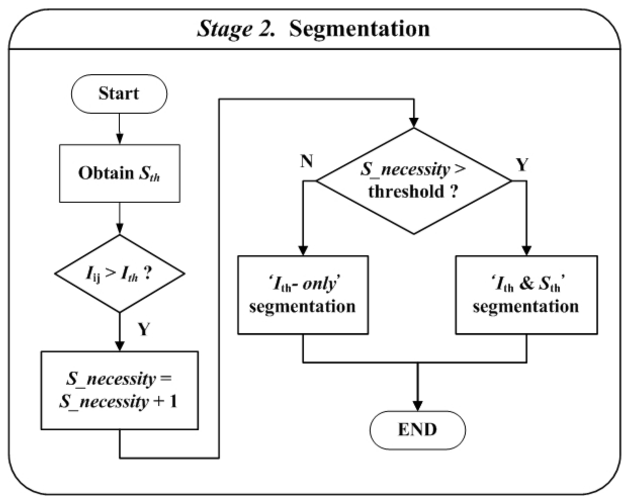


Fig. 9. Stage 2- Segmentation.

F. *Stage 3 — Filtering*

The second stage process of filtering is depicted in Fig. 10. Binary image domain is used in this stage for much color information is not necessary for further processing. By means of connected component labeling (CCL) of binary image, pixels connecting with one another are encoded to components along with labeling. Instead of interpreting pixel by pixel, only several remaining components on the image are to be observed. Furthermore, regarding the characteristics of lane-markings, it is much easier to determine if a component is valuable to be analyzed. Lane-markings have distinct characteristic of length and width ratio, using this as constraint for filtering, final result of HSILMD is observed in Fig. 11.

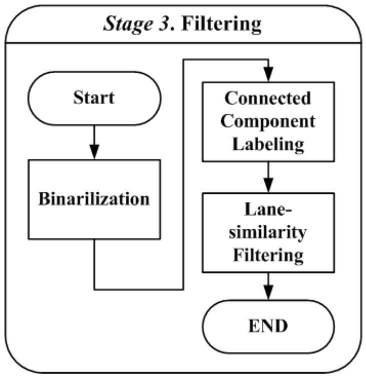


Fig. 10. Stage 3- Filtering.

Fig. 11. Final Result of HSILMD.

III. Comparisons and Experiments

A. Comparing HSILMD with FCM on RGB

The proposed HSILMD scheme uses FCM to determine threshold of intensity in HSI color model. To emphasis the advantage of choosing HSI color model instead of RGB model, a simple comparison is carried out in RGB color model based on the same technique. As there is no particular element nor value of either R, G and B to distinguish lane-markings in an image, both R, G and B values of the overall image are recorded and passed to FCM for both of the three thresholds. Segmentations using these thresholds are shown in Fig. 6.(b) and Fig. 7.(b). It is observed that using RGB color model based on FCM is meaningless in revealing lane-markings.

B. Comparing CBS with HSILMD

In order to further prove the results yielded by the proposed method, it is compared with another appreciative work "Lane Detection using Color-Based Segmentation" (CBS) by Kuo-Yu Chiu *et.al*. As a brief explanation of the work, it performs lane-marking detection with RGB color model, with the fact that difference between RGB of pixels of road surface is less than 25, a ROI is defined aiming to observe the gray level distribution of pixels which meets the condition. The gray level with largest amount of pixels is recorded and thresholds *th_head* and *th_tail* are defined accordingly.

On implementation, it is observed that the algorithm works well on some of the test images. However, some of the results are not satisfactory in segmenting lane-markings when lightened road surface is encountered. Further experiments are carried out with connected component labeling with component area superior to the size of 200 pixel^2 is filtered. Based on preliminary filtering with the two core algorithms, it is observed in Fig. 12 that CBS could not perform good segmentation, leaving large portion of pixels connected, where proposed HSI-based method performs better in segmenting lane-marking unconnected to other noises. Fig. 8 shows final results under complete CBS method with width of connected-pixel concerned. Miss detection of lane-marking of CBS shown in Fig. 13.(a) and (b). Segmentation results in this section can be compared with original images in Fig. 14.(a) and (e) respectively.

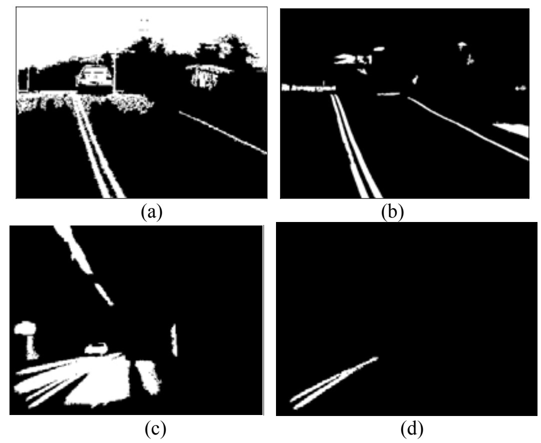


Fig. 12. Connected-Component Filtering with Area Size Constrained, (a) and (c) Results by CBS, (b) and (d) Results by HSILMD.

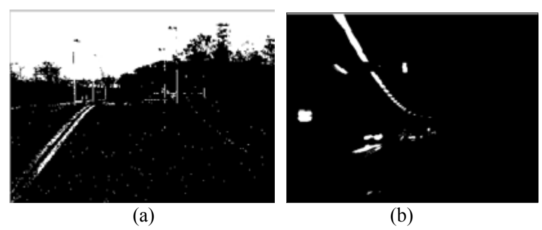


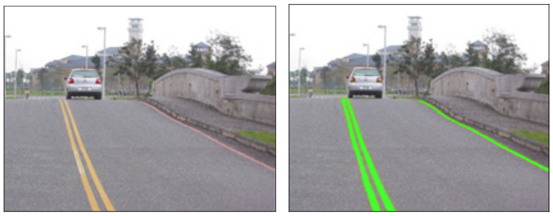
Fig. 13. Miss Detection of CBS.

C. Experimental results

From the above sections, some of the results performed by the proposed method are presented, in this section a more complete set of results are attached to show the ability and performance of the system dealing with various road environments. Tests are carried out with 24-bit color images captured by digital camera and some are surfed from the internet, both in JPEG format with resolution of 320×240. Platform for computation is with Intel Pentium M 1.73GHz core and 1GB memory.

Results of HSILMD including tunnel with bright lighting, an overcast day with both white and yellow lane-markings, and crushed-stone roads with red and yellow markings are shown in Fig. 14. Detected lane-markings on the images of either color are superimposed as with bright green and bright red for ease of observation. Corresponding computation time consumption of each stage of the results in millisecond (ms) is recorded on Table I.

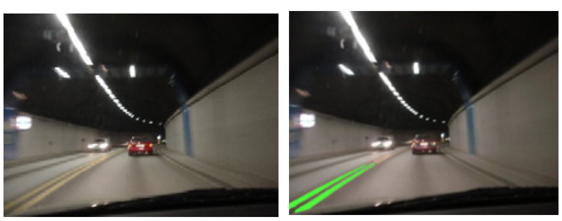
(a) Road scene taken in campus.



(b) Road scene taken in campus with more noises.

(c) Road scene taken in campus during nighttime.

(d) Traffic scene image provided by MATLAB



(e) Traffic scene taken in tunnel. *

(f) Traffic scene taken in country side. *

(a) – (c) Images taken by experimental equipment.
(d) – (f) Other images (* obtained from the internet).
Fig. 14. Experimental Results of HSILMD.

Table I.
Computational Time consumption for HSILMD in millisecond (ms).

Fig. 14	FCM analysis	Threshold evaluation	Similarity Comparison	Overall
a	1.512	1.461	7.75	10.723
b	1.618	1.552	1.023	4.193
c	1.486	3.71	4.284	7.237
d	1.866	2.268	3.3	7.434
e	1.51	1.52	2.95	5.98
f	1.51	1.43	4.23	7.17
Average	1.584	1.616	3.922	7.123

IV. Conclusion

In this study, a new lane-marking detection scheme HSILMD is proposed. The advantages of using HSI model for lane-marking detection is that simple threshold of intensity could perform well segmentation of lane-markings. The scheme indeed consumes lower computational costs compared with one using RGB model, for which both values are concerned. Furthermore, it is difficult to determine threshold(s) in RGB model for segmenting lane-marking with different colors. In HSILMD, simple thresholds with saturation and intensity values avoid influences of brightness of road effectively, which is also adaptive for different lane-marking colors.

The proposed method achieves the goal of lane-marking detection for either color with satisfactory results, computational consumption is reduced compared to the same scheme using RGB model. On going task is to derive a more adaptive mechanism in determining the incorporation of *S* value instead of using a pre-defined threshold.

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