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LANE MARKING DETECTION AND TRACKING

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ABSTRACT

Visually detecting and tracking lane markings on the road is a difficult task. The challenges faced on the road are different lighting, raining, poor lane markings, and objects on the road. This paper presents a different method to detect and track lane markings. The system carefully selects region of interests from the road image for image processing and recognition, avoiding the need to process large part of the image. The feature extraction is based on modified local threshold that is robust to different lighting condition. The line recognition is based on template matching that imitates the orientation columns of visual cortex. Detection of lane marking is done by scanning the road image for line pattern and the line is trace to complete the detection. When detection is complete, the system will track the lane marking with simple alignment algorithm. The lane marking detection and tracking system was tested on the road, in speed up to 70 km/h. The system is able to detect lane markings under cast shadows, variable ambient lighting and raining conditions, with low processing power.

Keywords: lane marking detection, vision, local threshold.

INTRODUCTION

Lane markings are one the most important road information for drivers to drive safely and efficiently. One of the present challenge of computer vision in autonomous vehicle is the ability to recognize lane markings, under different lighting condition, in a fast and robust method. Some methods are capable to detect straight lines, while some can detect curve lines at the expense of high computation.

Lane marking detection generally consist of feature extraction and algorithm to interpret the features detected. With few exceptions such as (Kluge and Lakshmanan, 1995) that uses deformable template model onto the intensity gradient of the input image directly. There are various lane marking feature extraction used, such as edge detection (Miao, Li, and Shen, 2012), (Dickmanns and Mysliwetz, 1992), local thresholding (Lipski *et al.*, 2008), (Shi, Kong, and Zheng, 2009), (Pollard, Gruyer, Tarel, Ieng, and Cord, 2011), (Revilloud, Gruyer, and Pollard, 2013), ridgeness (López, Serrat, Cañero, Lumbreras, and Graf, 2010), Hough transform (Meuter *et al.*, 2009), contextual features (Gopalan, Hong, Shneier, and Chellappa, 2012). Some works require certain image processing, such as perspective transformation (Lipski *et al.*, 2008), before the features are extracted.

The algorithm used to analyse or interpret the extracted features is dependent on the type of feature extraction or approach used. A deformable template is used on the intensity gradient of the input image, and go through iteration process until it meets the road line in the image (Kluge and Lakshmanan, 1995). Other method used are lane modelling and fitting method (López *et al.*, 2010), (Revilloud *et al.*, 2013), voting (Meuter *et al.*, 2009), and K-means cluster algorithm (Miao *et al.*, 2012). For tracking the lane markings, the algorithms used are Kalman filter with Interacting Multiple Models algorithm (Meuter *et al.*, 2009), and particle filter (Gopalan *et al.*, 2012).

There are few work done that imitate some concept in biological vertebrate vision such as in (Dickmanns and Mysliwetz, 1992) by identifying the lane markings' edge size and orientation in the initial stage of visual processing. Hubel and Wiesel (Hubel and Wiesel, 1962) shows that the primary visual cortex has orientation columns. The neurons in this region are excited by visual line stimuli of varying angles. This concept is applied to this current work, to match the detected possible object with line template of different orientation.

In this paper, the feature extraction of lane marking is based on local threshold. Unlike previous works, we extract features only from selected regions of interest. The features are used to determine if it is a possible lane marking. The features are matched with a collection of varying line orientation template, consisting of areas of excitatory response and inhibitory responses, similar to the orientation columns in the visual cortex. This matching method will determine if the feature is a lane marking and the lane marking's orientation.

Our contributions include 1) the development of a modified local threshold algorithm specifically road lane marking extraction, 2) line recognition imitating the orientation column, and 3) a different processing flow.

LANE MARKING DETECTION AND TRACKING

The hardware used in this system is a webcam and a laptop. The program runs mainly in MATLAB. The acquired video images' resolution is 432x240, with frame rate of 30.

Figure-1 shows the processing structure of the lane marking detection system, consisting of three levels. The low level is the feature extraction based on local threshold, middle level is the recognition of lane marking and its orientation using template matching, and lastly the high-level that carry out the tracing and tracking of lane

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markings. At the start of the system, a 24x24 pixel sized region of interest (ROI) scan through the bottom rows of the image to search for possible lane marking. When the possible lane marking is identified and its orientation known, the rest of the lane marking is traced. After both left and right lane marking is fully detected, the system will keep track of the lane marking as the vehicle drives on the road.

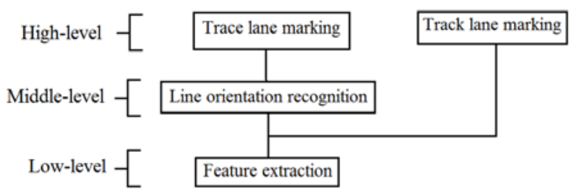

Figure-1. Processing structure.

Features extraction

To extract features from the ROI, the ROI image goes through few stages of analysis, to avoid inaccurate extraction and to ensure successful feature extraction from low and high contrast image. If possible lane marking is detected, ROI will be aligned before being process at the line recognition stage. Compared to other local threshold algorithms (Lipski *et al*., 2008), (Shi *et al*., 2009), this algorithm is specifically for extracting lane marking on the road, avoid extracting noises on road surfaces, and uses less computing time.

Firstly, the local contrast V_{diff}, the difference between maximal and minimal value, is determined. If V_{diff} is smaller than the threshold $T_{contrast}$ means that there's a very small contrast in the image, shown in

Figure-2(a). The threshold T_{pixel} for the pixel value of the possible lane marking, will be set to the maximal pixel value V_{max}. If exceed, the image shows a high contrast, shown in

Figure-2(b).

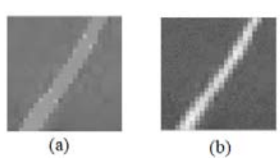

Figure-2. (a) Road line with low contrast. (b) Road line with high contrast.

The following stage is to determine the threshold T_{pixel} for high contrast ROI. The number of pixels that are within range of a certain level of the minimum pixel value, V_{min} and (V_{min} + V_{diff} /2), are counted. When the total number of pixels are lower than T_{ROI} % of the total number of pixel of the ROI, the pixel value of the possible lane marking has higher pixel value range. T_{pixel} will be set to a slightly lower value than V_{max}. On the other hand, when it is above T_{ROI} % of the total number of pixel of the ROI, the pixel value of the possible lane marking has lower pixel value range. T_{pixel} will be set to a much lower value than V_{max}.

The third stage will be to extract out the possible lane markings from the ROI by using the threshold T_{pixel}. Pixels that are above T_{pixel} will be set to white. The algorithm flow is shown in

Figure-3.

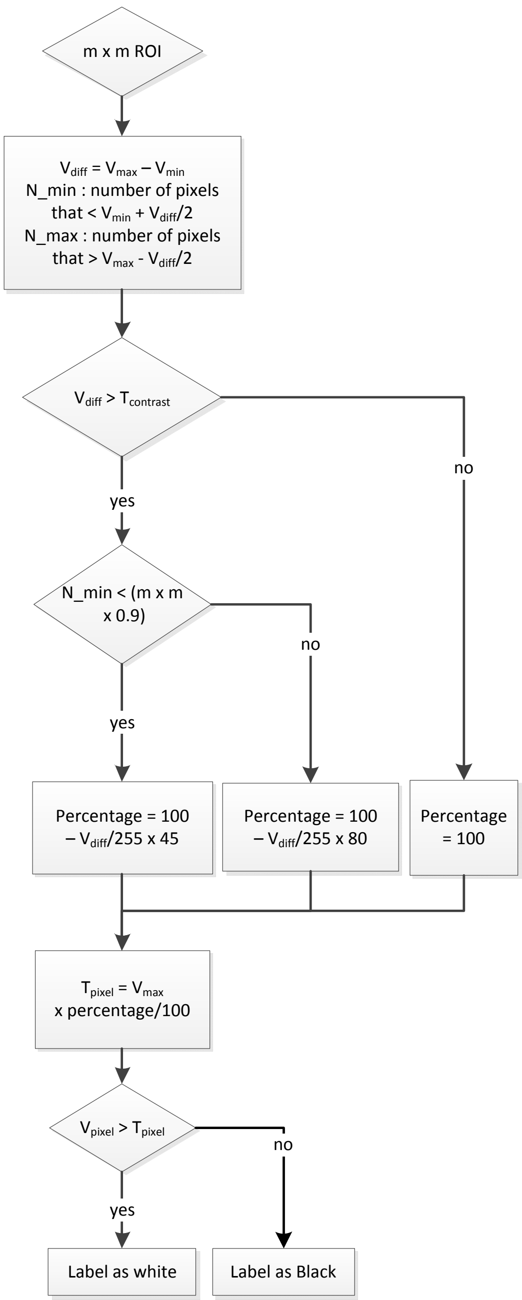

Figure-3. Feature extraction algorithm flow.

Line recognition

The line recognition is based on template matching. This process is to determine if the feature is a line and in what orientation the line is. Knowing the

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orientation of the line, the next section of the line can be estimated for tracing purposes, explained later section. The extracted feature image is matched with a collection of line template of different orientation, shown in

Figure-4. This method imitates some of the concept in the orientation columns of the visual cortex.

Figure-5 shows an example of a receptive fields of one of the template. This is similar to the simple cortical receptive fields (Hubel and Wiesel, 1962). White area gives the excitatory response while the dark area gives the inhibitory responses. The extracted feature needs to activate enough response from both areas in order to have successful matching.

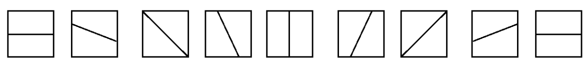

Figure-4. Collection of line template of different orientation.

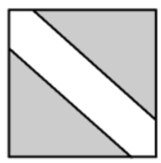

Figure-5. Receptive fields of a template. White area gives the excitatory response. Dark area gives the inhibitory responses.

Line tracing

The system process the image by selecting various region of interests (ROI) throughout each input frame.

It begins by scanning for possible left and right lane marking in the road image. Once detected (ROI 1 in

Figure-6), the line orientation is identified and the position of the next section of the line (2^{nd} ROI in

Figure-6) can be estimated, as shown in

Figure-6. The first left road line is trace to the visible near end of the road (n-th ROI in

Figure-6). When both of the left and right lane marking has been searched and traced, the system will proceed to track the line as the vehicle moves along the road. After a road line lane marking is successfully trace, the system stored the positions of the ROIs, which will be used for tracking purposes.

The region of interest (ROI) are square shape and vary in size according to the distance of the lane from the vehicle. ROI will be smaller as it moves further from the vehicle, shown in

Figure-7.

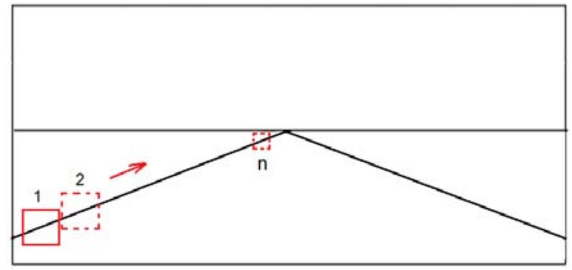

Figure-6. Left lane marking detection and tracing.

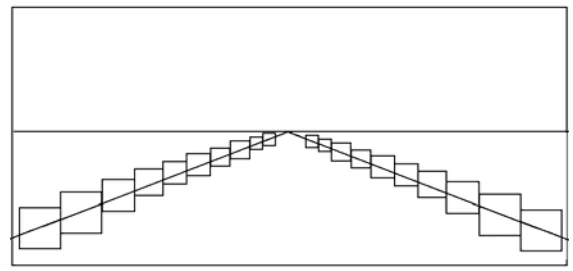

Figure-7. Changes in ROIs' size according to the distance.

Tracking

Tracking of the lane marking is carried out after the left and right lane markings are successfully detected and traced. To track the lane marking as the vehicle moves on the road, the system uses the positions of ROIs of the traced lane markings to check if the line in the ROIs has shifted in its positions in the new image frame.

This process uses the same feature extraction mentioned earlier to extract line feature in the each of the selected ROIs, and a simple alignment algorithm is used to detect changes of the line position in each ROIs. The system will then compute and update the new positions of the ROIs of the lane markings. Tracking continues throughout the frames using the updated positions of the ROIs of the lane markings.

Using the positions of the ROIs of the left and right lane markings, the system is able to detect if the vehicle is within the lane or has departed from the lane.

EXPERIMENTAL RESULTS

Feature extraction

The feature extraction gave promising results, giving good results in shadow area and in low contrast situation. Low contrast situation will occur when lane marking is further ahead and gets blur, faded lane marking colour, road affected by shadow, bright sunlight reflection on the road, or during raining.

Figure-8 shows the line extraction of road line with low contrast under shadowed region. The left image (a) shows the location of the ROI on the road, the middle image (b) is the enlarged image of the ROI, and the right image (c) is the extracted line image. Despite its low contrast, the algorithm is able to give sufficient extraction. Figure-9 shows another line extraction from a low contrast ROI taken outside of the shadowed region.

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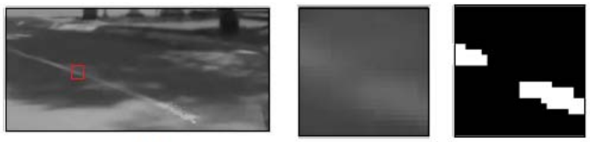
(a) (b) (c)

Figure-8. (a) ROI with low contrast under shadowed region. (b) Enlarged image of the ROI. (c) Line extraction of the ROI.

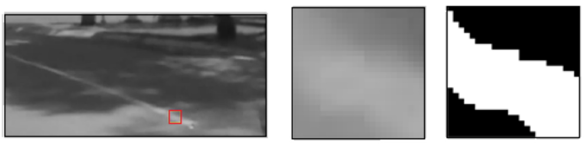
(a) (b) (c)

Figure-9. (a) ROI with low contrast under brightly lit region. (b) Enlarged image of the ROI. (c) Line extraction of the ROI.

Line recognition

The line matching method is able to give good results for single line

Figure-10, and double line Figure-11. Both figures shows the image of the selected ROI, the extracted line feature and the result of the recognition. In cases of double line, the accuracy of the orientation recognition is slightly affected.

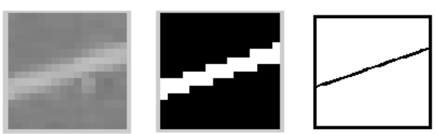
(a) (b) (c)

Figure-10. Line recognition of single line (a) image of the ROI. (b) Extracted line feature. (c) Result of the line recognition.


(a) (b) (c)

Figure-11. Line recognition of double line (a) image of the ROI. (b) Extracted line feature. (c) Result of the line recognition.

Tracing

Figure-12 shows sample results of the tracing of left and right lane marking under few different conditions. Tracing is successful for continuous or broken single line and double line, under good weather condition. When raining, the road line becomes visually less visible, and reflection of lights and rain droplets on the windscreen affects the feature extraction. The movement of the wiper of the vehicle affects little on the performance of the system.

Tracking

The system is able to track the lane marking as the vehicle moves within inside of the lane or out of the lane. However, the result is affected during the raining situation due to the reflection of the rain water all over the road. Road markings or objects that comes within the ROIs slightly affects the lane marking tracking. The system will not able to track the lane marking if the vehicle make a sudden swerve off the lane.

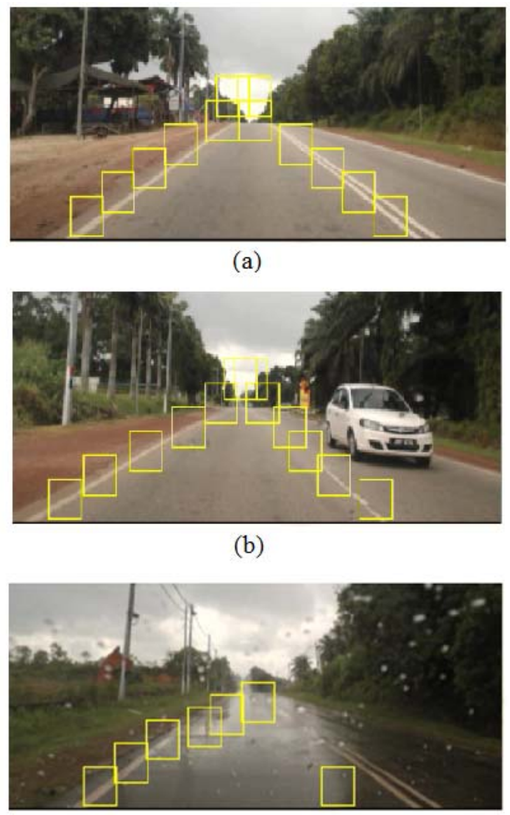
(a)
(b)
(c)

Figure-12. Sample results under different situations: (a) good weather condition, double line lane marking; (b) good weather condition, broken single line lane marking; (c) raining condition.

CONCLUSIONS

In this paper we presented a different method of lane marking detection and tracking system using a camera and a conventional laptop. The use of selective ROIs and the modified local threshold algorithm give good feature extraction at different lighting situations. It also require less processing speed by processing only the necessary parts of the road image. Imitating visual cortex's orientation columns for line recognition shows good recognition result, even when the line is not clear or broken. The line recognition and tracing method is able to detect left and right lane markings without the need to process large part of the image. The simple tracking method is able to track the lane marking as the vehicle swerves from the lane. The system has been tested on the road with the vehicle's average speed of 70 km/h.

The current system needs to be fine tune for better detection and tracking under raining situation. The high-level processing stage can be improved for better detection and tracking of different condition of lane marking.

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