

# Forward Vehicle Detection System Based on Lane-Marking Tracking with Fuzzy Adjustable Vanishing Point Mechanism

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*Abstract—Based on lane-marking tracking with fuzzy adjustable vanishing point mechanism, this paper presents robustness forward vehicle detection system. Compared to most of the detection systems with a large curvature of road trend, which are not effective for the routes to detection and marking. Therefore, follow the current image frame, the proposed system calculate the error between lane detection point and regressed lane-marking lines, and then fuzzy inference system derive and update the proper vanishing point in next image frame. The algorithm proposed in this paper can be carried out for different road situations and adaptive tuning of the car camera has been successfully tested and proven for the highway to the robustness of the system.*

**Keywords—**Forward vehicle detection, Lane-marking tracking, Fuzzy adjustable vanishing point.

## I. INTRODUCTION

Traffic accidents often occur almost daily. Since the traffic environments are very complex and difficult to predict the dangerous situation, so that there are many driver assistant systems have been proposed for supporting the vehicle driver significantly avoid the occurrence of accidents.

In the preliminary study, an intelligent vehicle collision-avoidance system with vision perception and fuzzy decision making has proposed [1]. However, lane area is an important region of interested (ROI) in driver assistant issues. Therefore, we proposed a novel algorithm by means of Kalman Filter for lane detection and tracking [2], [3] and implemented it in a multi-core DSP embedded system [4]. Robust road and forward vehicle detection are important topics in ITS. Based on Illuminant Invariance, [5] has proposed road detection approach. Forward vehicle detection has proposed and implemented in DSP for driving assistant system [6], [7]. In our preliminary study, collision warning system has proposed by composed of lane departure and forward vehicle detection with fuzzy decision making [8]. In this paper, based on fuzzy adaptive vanishing point method for lane-marking tracking, we propose a robust scenario of detecting forward vehicle for dealing with collision avoidance assistant system. The

objective of the proposed system is to detect vehicle in different road situation with features of real-time, robustness and precise. Therefore, the robust feature for ROI of lane-marking and vehicle detection must be required. In this study, fuzzy adaptive vanishing point mechanism adopted to provide the requirement mentioned above.

The remainder of this paper is organized as follows. Section II describes the architecture of the proposed system which is composed of lane-marking tracking and forward vehicle detection. Section III introduces the fuzzy adaptive vanishing point for lane-marking tracking. The experimental results present in Section IV. Section V is conclusion and future work.

## II. SYSTEM ARCHITECTURE

The architecture of the proposed system is shown in Figure 1. The objective of lane-marking tracking (LMT) unit is to detect and track the proper ROI of lane from the camera captured image. The results of LMT are errors between the regressed lane-marking lines and detecting points, and feed into fuzzy adaptive vanishing point (FAVP) to adjust the proper vanishing point position for LMT and forward vehicle detection (FVD) unit. Hence, FVD could correctly detect forward vehicle following the proper detecting ROI and vanishing point.

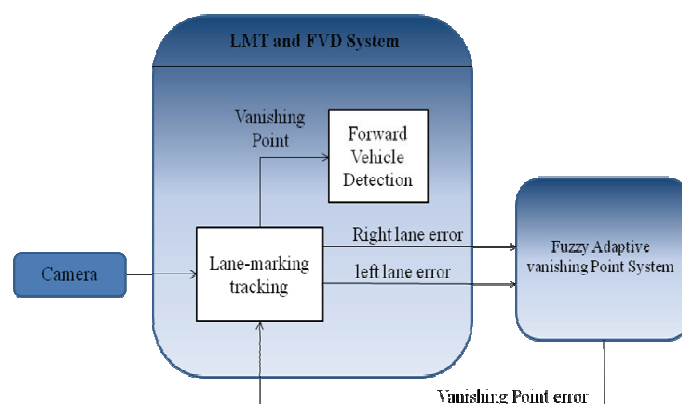


Figure 1. System Architecture

### A. Lane-marking Tracking

The flowchart of lane-marking tracking is depicted as Figure 2 and describes in detail as following:

Step 1. To convert input frame to a grayscale “R+G-B”. This special intensity information can enhance the character of the lane-marking.

Step 2. If lane initial point can’t find out, then executes the lane-marking detection process, else process lane-marking tracking.

Step 3. Employ linear regression to approximate the current lane-marking. Assume the data points of lane-marking can be approximated as a line by

$$y = mx + b \quad (1)$$

where  $m$  and  $b$  are the slope and  $y$ -intercept of the lane in image plane respectively. When the lane-marking line  $D_i(x, y)$  is extracted by Nearest Neighbor Peak (NNP) in  $i^{th}$  row, lane curve can be approximated by those lane-marking data points in image [5]. The advantage is that some fault lane-marking data can be restrained. The simple linear regression is considered in this paper. The approximated slope  $\hat{m}$  is evaluated as

$$\hat{m} = \frac{Cov(x, y)}{Var(x)} \quad (2)$$

where  $Cov(x, y)$  and  $Var(x)$  denote covariance and variance respectively, and described as below

$$Cov(x, y) = \sum_{i=R_u}^{R_l} x_i y_i - \bar{x} \bar{y} \quad (3)$$

$$Var(x) = \sum_{i=R_u}^{R_l} (x_i - \bar{x})^2 \quad (4)$$

where  $\bar{x}$  and  $\bar{y}$  are the mean of  $x$  and  $y$  respectively,  $R_u$  and  $R_l$  are the upper boundary and lower boundary of ROI. Thus, the approximated  $y$ -intercept of the lane  $\hat{b}$  can be calculated as below

$$\hat{b} = \bar{y} - \hat{m} \bar{x} \quad (5)$$

The detected lane-marking line can be regressed with parameter  $\{\hat{m}, \hat{b}\}$ . However, the pattern resolution depends on the distance between camera lens and pattern in real world. The farther the distance is, the lower the resolution is. For this reason, a weighted regress analysis is proposed to handle the lane-marking points that are detected in lower resolution area. The weighted series  $w_r^i$  determine by power series with a constant ratio  $\lambda$ , the detected lane-marking points that are nearer bottom of ROI is given the larger weight. Then, the weight set have to be considered when the regression analysis is performed. It only has to modify the mean  $\bar{x}$  and  $\bar{y}$  as follows:

$$(\bar{x}, \bar{y}) = \left( \frac{\sum_{i=1}^{R_l-R_u} w_r^i x_i}{\sum_{i=1}^{R_l-R_u} w_r^i}, \frac{\sum_{i=1}^{R_l-R_u} w_r^i y_i}{\sum_{i=1}^{R_l-R_u} w_r^i} \right) \quad (6)$$

The regressed lane-marking is based on a proper vanishing point in front of tracking area. From Wikipedia, a vanishing point is a point in a perspective drawing to which parallel lines not parallel to the image plane appear to converge. If the trend of road is straight line, a fixed vanishing point could provide correct lane-marking following the regressed detection points. However, a fixed vanishing point could not obtain correct lane-marking for a road trend with curvature. The vanishing point should be varied follow the road trend to obtain correct ROI for vehicle detection. In this study, a vanishing point adjustable mechanism based on fuzzy inference is proposed in Section III.

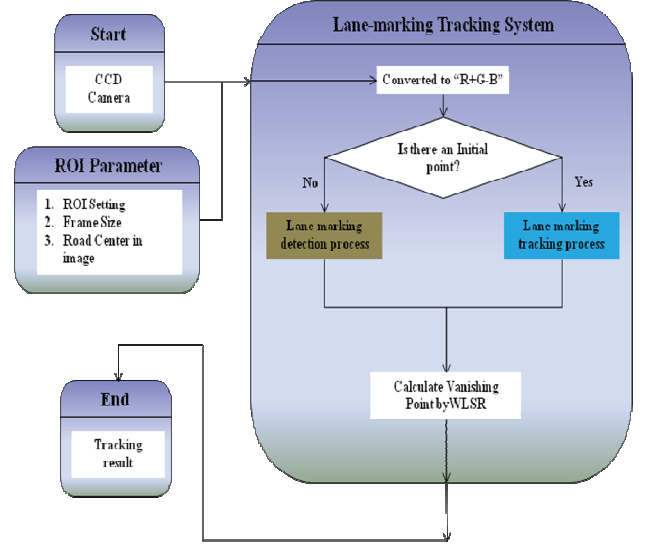
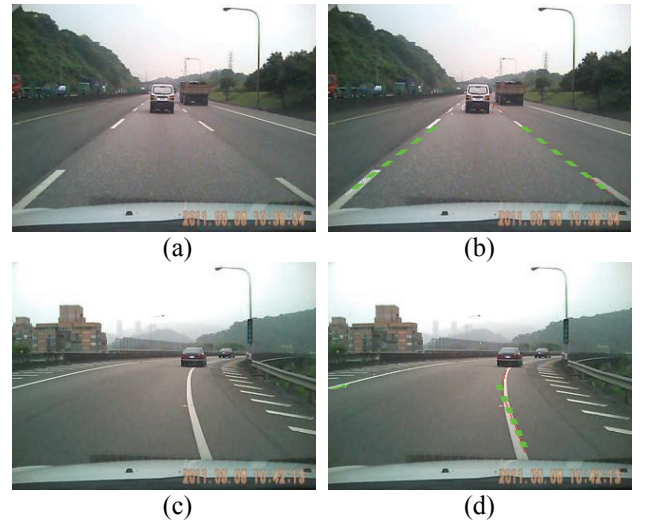


Figure 2. Flowchart of Lane-marking tracking

The proposed LMT algorithm needs only partial region to detect lane-marking location in each frame. The tracking results of LMT are lane-marking area (LMA) in the image plane. For different road situations, the original image frame shown as left column in Figure 3, and corresponding tracking result shown as right column in Figure 3. Following the results, the proposed LMT algorithm presents precision and robustness features. It can reduce the complexity of vision data processing and meet the real-time requirements.



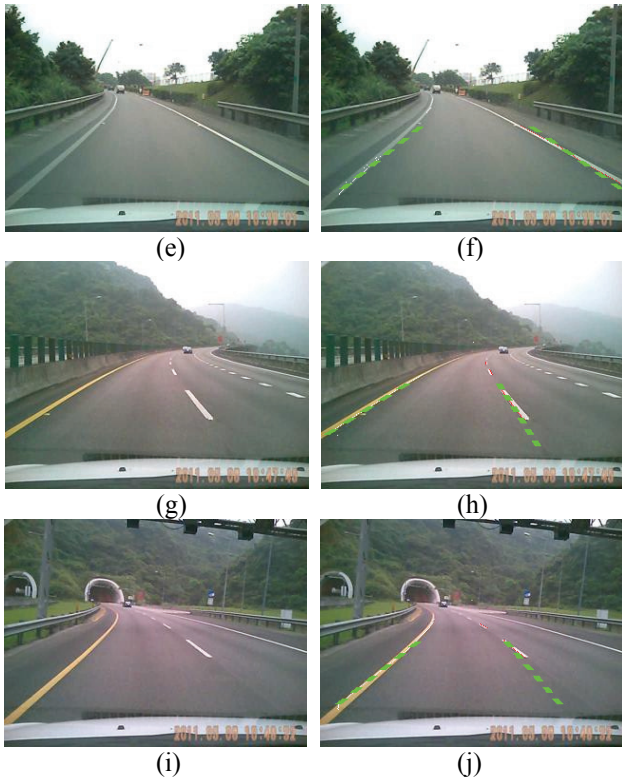


Figure 3. The result of Lane-marking tracking

### B. Forward Vehicle Detection

The proposed FVD algorithm is depicted as Figure 4, and describes as following five steps:

Step 1. Extract detection box following the ROI from LMT to obtain the luminance information for vehicle detection. The result is shown as Figure 5(b).

Step 2. Calculate average luminance parameter for threshold on the detection box by

$$\text{thresh} = \frac{\sum_{i=0}^N \sum_{j=0}^N Y(i, j)}{N \times N} \quad (7)$$

Step 3. Following the threshold, the original image make binary pattern by Eq. (8). The result is shown in Figure 5(c).

$$I(i, j) = \begin{cases} 1, & Y(i, j) < \text{thresh} \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

Step 4. Following a 3 x 3 matrix for binary image preprocessing, the erosion, dilation and connected components labeling (CCL) employed step by step for effective recognition. The results are shown as Figure 5(d) and Figure 5(e). Finally, based on the lane slope, a noise reduction mechanism is employed to clearly extract the object shown as Figure 5(f).

Step 5. Separate the object image into four independent areas shown as Figure 6. If the average luminance between Figure 6(a) and (b) is close, Figure 6(c) is greater than Figure 6(d). Following the above two conditions, the object in front of lane could be recognized as a vehicle. Then put a boundary mark for the object shown as Figure (7).

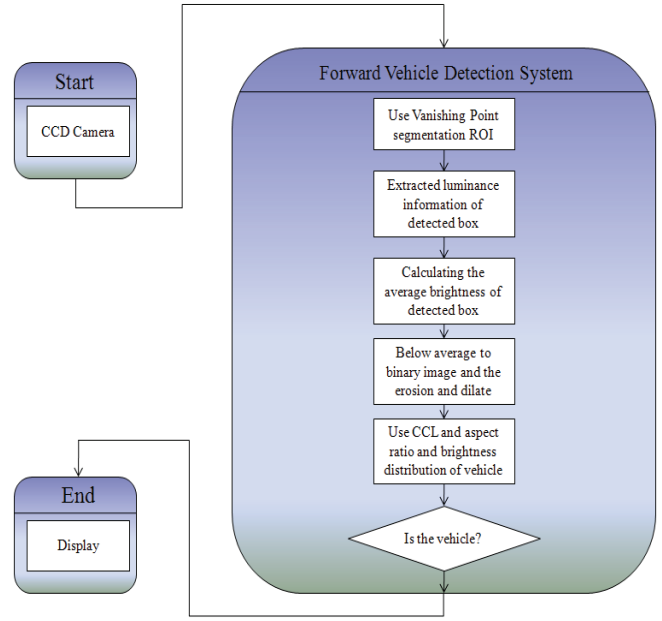


Figure 4. The system architecture of forward vehicle detection

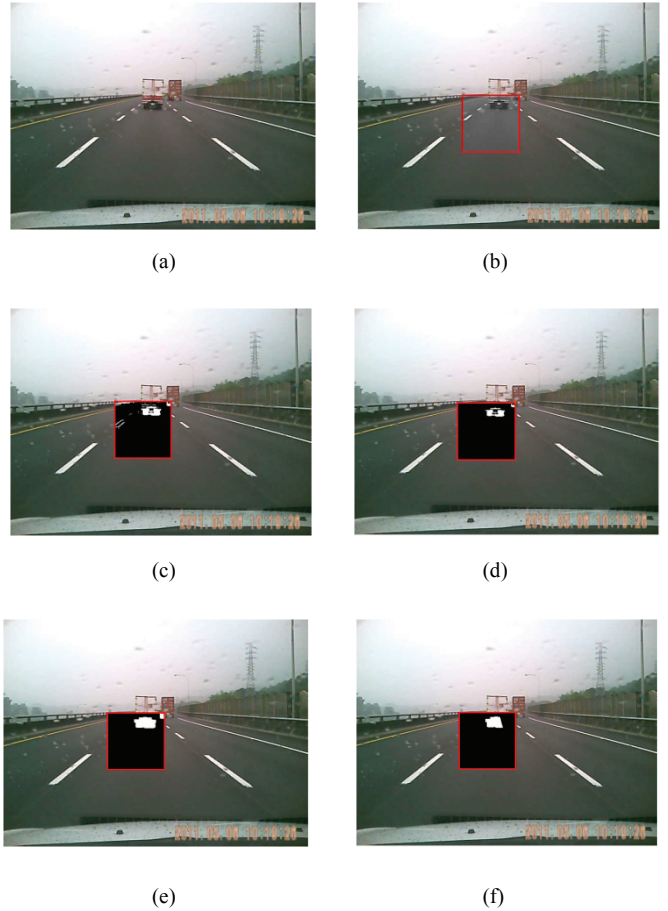


Figure 5. forward vehicle detection process (a) original (b) gray image (c) binary image by used threshold (d) erode image (e) dilate image (f) slope cut binary image



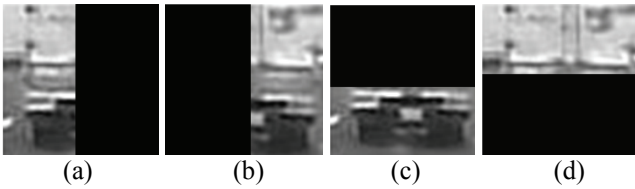


Figure 6. Vehicle luminance distribution (a) left (b) right (c) down (d) up



Figure 7. The result of forward vehicle detection

### III. FUZZY ADJUSTABLE VANISHING POINT

A proper vanishing point could enhance the accuracy for lane-marking line and forward vehicle detection. Since vanishing point provide important reference location for lane regression line. If the road trend is straight line, the ROI for vehicle detection should match the road trend. Therefore, the forward vehicle could be detected following the road trend. However, if the road trend is curvature line shown as Figure 8, the ROI could not match the road trend. Therefore, the forward vehicle detection could be failed.

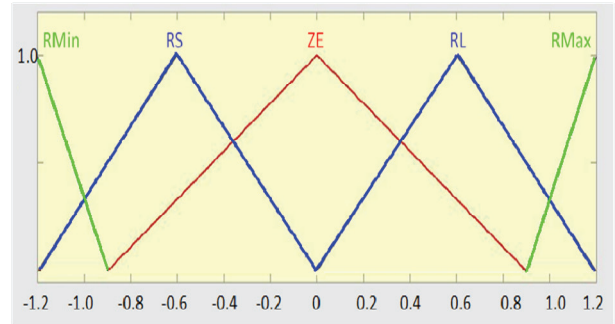


Figure 8. the vanishing point does not match the road trend

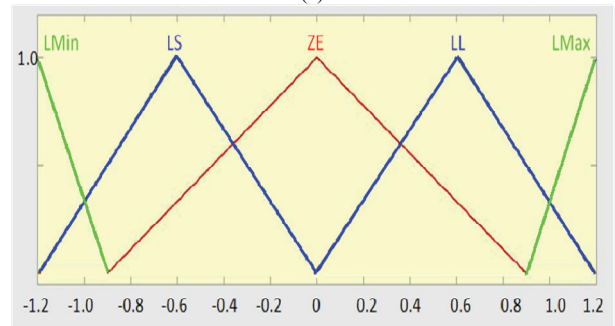
This paper uses the road line detection points and the parameters of the linear regression to calculate the average error of left and right lane. And then, feed left error and right error into fuzzy inference system to adjust the vanishing point position. If the road trend is straight line, the left and right error should be approximately equal. The vanishing point position could not modified at next frame. However, left and right error exhibits larger value and does not match in the situation that road trend is curvature line. Therefore, a fuzzy inference system could provide adjustable mechanism for vanishing point under different error situation.

Following the lane trend in Figure 8, the actual error of the lanes exhibit much larger value, the direction of vanishing

point should be quickly adjust at next image frame. In this study, following over 30000 image frames error measurement, the fuzzy knowledge base (FKB) has derived as below. The membership functions of right lane error and left lane error present as Figure 9(a) and Figure 9(b) respectively. The error value is divide into five linguistic terms: the ZR (ZeRo) is error equal to the set value, RL (Right Large) is the error a little large than the set value, RMax (Right Max) is the error much larger than the set value, RS (Right small) is the error a little small than the set value, RMin (Right Min) is the error much smaller than the set value. The output is the adjust value of vanishing point defined as Figure 10. There are nine singleton levels: VFR (Very Far Right) is add four pixels, VR (Very Right) is add three pixels, R (Right) is add two pixels, SR (Small Right) is add one pixel, Z (Zero) is add zero pixel, VFL (Very Far Left) is reduce four pixels, VL (Very Left) is reduce three pixels, L (Left) is reduce two pixels, SL (Small Left) is reduce one pixel. And the add or reduce pixels limit is twelve pixels. The rule-base of the proposed adjust vanishing point fuzzy inference system describes as TABLE I.



(a)



(b)

Figure 9. membership function of lane error (a)right lane (b)left lane

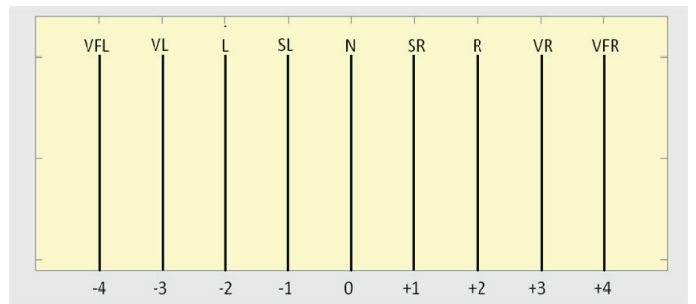


Figure 10. membership function of adjust vanishing point value

TABLE I. RULE-BASE TABLE FOR ADJUST VANISHING POINT

Error_R \ Error_L	RMin	RS	ZE	RL	RMax
LMin	Z	SL	L	VL	VFL
LS	SR	Z	SL	L	VL
ZE	R	Sr	Z	SL	L
LL	VR	R	SR	Z	SL
LMax	VFR	VR	R	SR	Z

The unit is pixel

If the error of right line has negative value, then a positive value correct the vanishing point. If the error value is positive, and vice versa. So according to this vanishing point of the proposed adaptive fuzzy inference system, the modified result of Figure 8 is shown as Figure 11. Based on the results, the proposed adaptive mechanism for vanishing point can provide more accurate and stable capability for lane-marking tracking and vehicle detection.



Figure 11 Match to the vanishing point by fuzzy inference system

#### IV. EXPERIMENTAL RESULT

The experiments of the proposed system is composed of (A). Lane-marking and tracking, (B). Forward vehicle detection. In all experiments, the captured image size is 320 x 240 with 30 frames per second (FPS).

##### A. Lane-Marking and Tracking experiment

The experiment results of lane-marking tracking present as Figure 12. The left and right column image is non-matched vanishing point and matched vanishing point respectively. Following the experimental results, the vanishing point could be effective adjust under the non-matched error and presents precised lane-marking tracking. From Figure 12(a)-(d), in the situation of the lane with curvature and forward with an obstacle, the lane-marking tracking results have more precised under the adjusted vanishing point. So that more effective regulation of the vanishing point will provide more effency in lane-marking tracking algorithm.

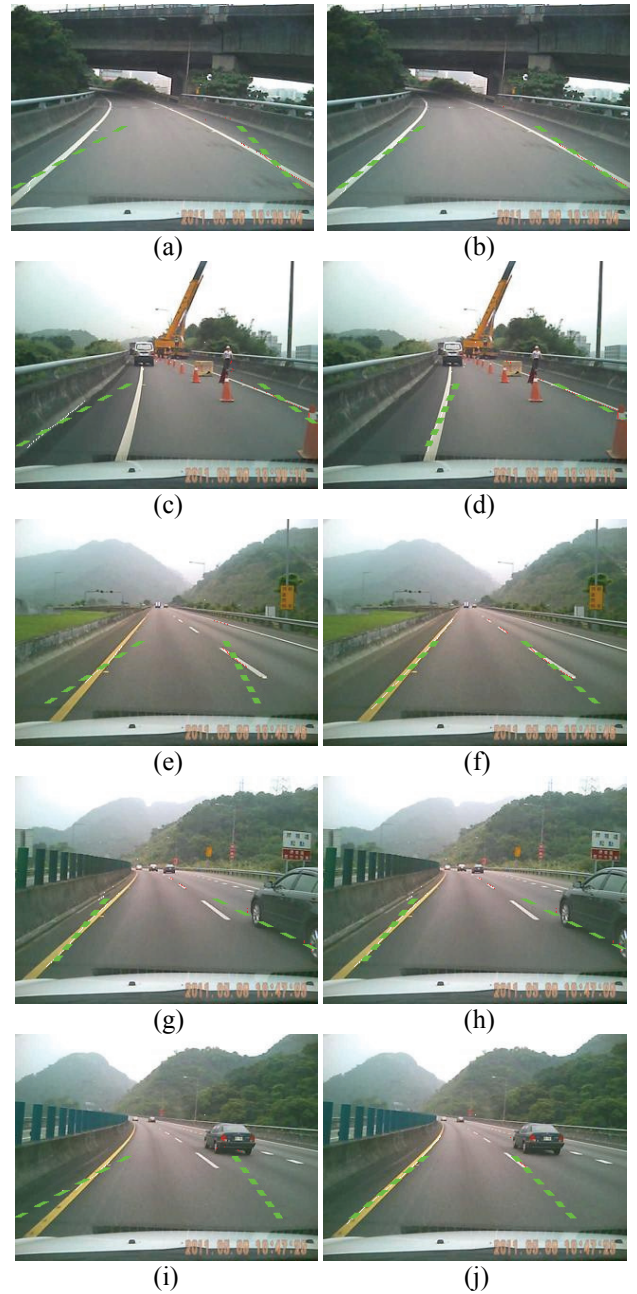


Figure 12. Compare with non-matched and matched vanishing point images for lane-marking tracking

##### B. Forward Vehicle Detection experiment

The experiment results of forward vehicle detection present as Figure 13. The left and right column image is non-matched vanishing point and matched vanishing point respectively. According to the corresponding images of Figure 13, proper vanishing point for proper detecting vehicle exhibits very important role. In the situation of road trend with curvature, the proposed system could adjust the vanishing point with more wider detection range. Therefore, the more effect provide more chance for detecting forward vehicle and/or obstacles. It enables drivers to be more for road safety improvement in security.

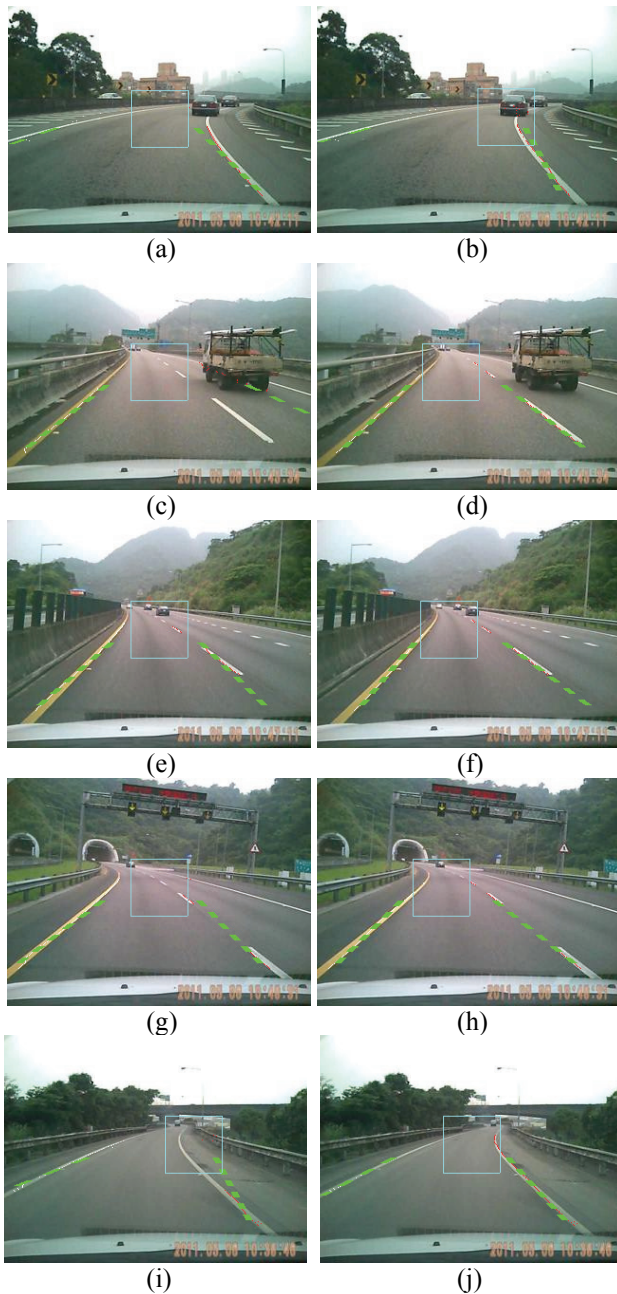


Figure 13. Compare non-matched and matched vanishing point images for forward vehicle detection

### CONCLUSION

In this paper, based on lane-marking tracking with fuzzy adjustable vanishing point mechanism, we propose a robust forward vehicle detection system. Follow the current image frame, the proposed system calculate the error between lane detection point and regressed lane-marking lines, and then fuzzy inference system derive and update the proper vanishing point in next image frame. The algorithm proposed in this paper can be carried out for different road situations and adaptive tuning of the car camera has been successfully tested and proven for the highway to the robustness of the system. Following the experiment results, the proposed fuzzy

adjustable vanishing point mechanism is very reliable and robust.

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