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Automobile Advance Alarm System Based on Monocular Vision Processing

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Abstract—**While the interests in intelligent vehicle increase, many people are having concerns about systems that offer the information of distance and relative speed between two cars. This paper presents an algorithm to obtain efficiently the distance between two cars.**

I. Introduction

Driver inattention and poor judgment are the major causes of motor vehicle accidents. Extensive research has shown that intelligent driver assistance systems can significantly reduce the number and severity of these accidents [1]. Compared with vehicles equipped with no crash warning system, vehicles equipped with crash warning systems can reduce more accidents. If the alarm is given a few seconds in advance of the collision, many accidents can be prevented [2]. Therefore, while the interests in intelligent vehicles increase, many people have concerns about systems that offer the information of distance and relative speed between two cars.

One of the most popular solutions today is based on radar technologies [3], [4]. The radar technology measures reflections from metal objects, and takes into account the Doppler effect in order to provide relative speed information. However, the high cost of radar systems limits their usefulness.

Given that the driving environment is designed around the human driver's ability for visual perception, it may look natural to search for vision solutions. Therefore, another family of solutions is based on image system with two cameras [5], [6]. Such systems are still rather expensive and require accurate calibration between the cameras.

The systems based on vision processing with only one camera are recently developed [7-10] and such systems are called "monocular vision system." This paper presents an automobile advance warning algorithm that is carried out using a monocular vision system.

Domain limitation via lane identification is proposed in order to efficiently detect advance vehicles. Dark pixel density is used to detect the existence of cars. The distance is calculated using the width between the left and right lanes and the relative speed between two cars is obtained with calculated distance. Finally, the alarm is given a few seconds in advance of the possible collision for drivers to keep safety distance.

The proposed algorithm was tested with actual images taken on the road. The 256-gray-level image is used for the simulation. The simulation results show that the maximum error is less than 1 m within the range of 50 m and less than 4 m within the range of 70 m. The simulation results show that more accurate results can be obtained by the proposed algorithm compared with the existing algorithms.

The proposed algorithm was implemented using a SoC kit. The included processor is the ALTERA Excalibur ARM EPXAnF1020C3. The image and the calculated distances are displayed via TFT-LCD and a 7-segment, respectively.

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II. Algorithm

Figure 1 shows the proposed algorithm for automobile advance alarm systems.

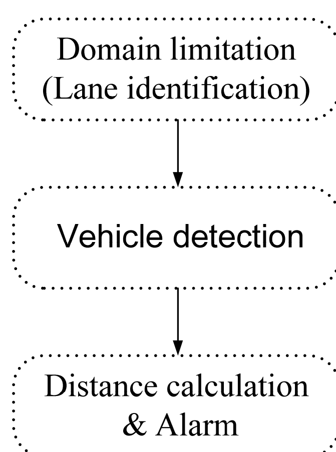

Fig.1. Algorithm for automobile advance warning system.

A. Domain limitation

The domain limitation via the lane identification is

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proposed in order to effectively detect the advance vehicle. The domain is separated into inside and outside of the lanes. The outside domain of lanes is not considered in order to exclude the domain where the advance vehicle does not exist.

In order to efficiently detect the lanes, we make the following assumption :

Assumption : The lane is approximately a straight line.

1) Edge detection

After applying Histogram equalization to the original image, Sobel filter is applied to the image for the edge-detection. The boundary between the lane and the road can be detected easily since the luminosity of the lane is high and that of the road is relatively low. Figure 2 shows the sharp edge found at the boundary of the lane and the road.

Fig 2. Edge detection.

2) Binarization

The binarization is applied in order to limit the levels of image data to "0" or "1", which makes it simpler to detect the advance vehicle. ("0" : 8-bit Gray level 0, "1" 8-bit Gray level 255)

3) The pattern of lanes

In Figure 3, L_o and L_i are the outer and inner lanes of the left lane and R_o and R_i are the outer and inner lanes of the right lane.

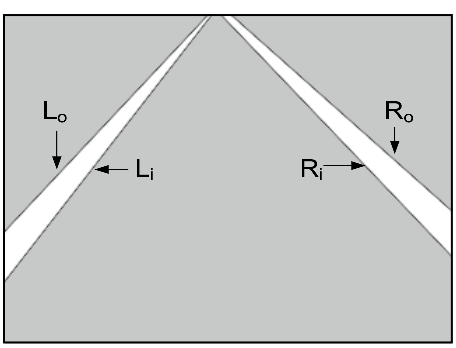
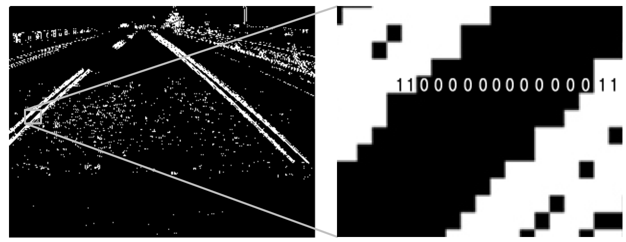


Fig 3. Definition of lanes.

Notice that there is a gap between L_o / R_o and L_i / R_i. Figure 4(b) is the enlarged image of the boxed portion in Figure 4(a). Figure 4(b) shows that some number of 0's appear between 1's. The 0's between inner and outer lanes indicate the gap between lanes.

4) Identification of inner lanes (L_i , R_i)

Pattern of lane : [1 0 0 0 … 0 0 0 1]



(a) (b)

Fig 4. Enlarged binarization image.

Step 1 : We find the points most matched with the pattern of the lanes. These points are called "$P_{candidates}$".

Fig 5. White dots denote $P_{candidates}$.

Figure 5 shows the detected $P_{candidates}$.

Step 2 : Choose any two points from the point sets in $P_{candidates}$ and calculate a line equation using the two points as

$$y = a \times x + b \tag{1}$$

a : slope of the line
b : y-intercept of the line
x : x-coordinate
y : y-coordinate

The calculated slopes of the lines are called $a_{\text{candidates}}$ and the calculated y-intercepts are called $b_{\text{candidates}}$.

Step 3 : From $a_{\text{candidates}}$ and $b_{\text{candidates}}$, choose the values satisfying the following conditions :

i) The slope of left lane must have a negative value and that of right lane must have a positive value.
ii) The slope value must be in some limited range.
iii) The y-intercept value must be in some limited range.

(The values for the limited range are defined by experiments.)

Step 4 : The numbers of occurrences of $a_{\text{candidates}}$ and $b_{\text{candidates}}$ are counted as shown in Table I.

TABLE I
Example of the occurrence counts

Range of values	Number of $a_{\text{candidates}}$
…	
0.81-0.82	5
0.82-0.83	4
0.83-0.84	1
0.84-0.85	0
…	
Range of values	**Number of $b_{\text{candidates}}$**
…	
100-102	5
102-104	3
104-106	2
106-108	0
…	

Step 5 : The ranges of values under some predetermined threshold values are discarded from Table I.

Step 6 : The mean values of the remained $a_{\text{candidates}}$ and $b_{\text{candidates}}$ are calculated, respectively.

Step 7 : The mean value of $a_{\text{candidates}}$ is defined as the slope of the lane. By the same way, the mean value of $b_{\text{candidates}}$ is defined as the y-intercept value of the lane.

Figure 6 shows the domain of image limited by the lane identification.

Fig 6. Limited image.

B. Vehicle detection

Figure 7 shows that the dark pixel density below the vehicle is very high. The reason is that the distance between the vehicle and the surface of the road is very short. Based on this observation, we can find the location of the vehicle. Figure 8 shows a detected vehicle. The location of the detected car is denoted as y_{car}.

C. Distance calculation & Alarm

The distance can be calculated using the width between lanes. Figure 9 shows that the longer the distance between cars, the shorter the width between lanes.

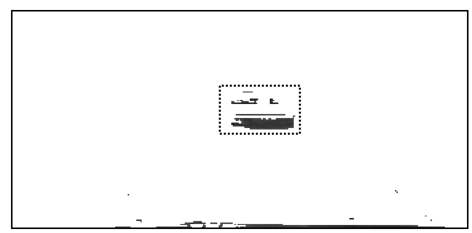


Fig 7. Dark pixel density.

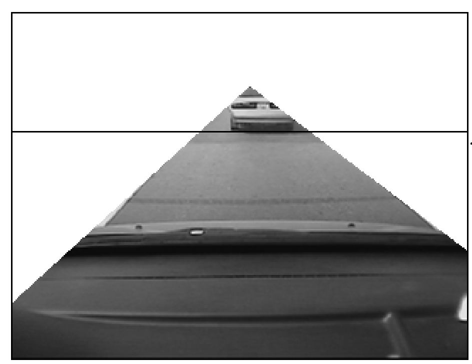


Fig 8. Vehicle detection.

The distance between cars can be calculated through the lane equation and the following algorithm :

Fig 9. The width between lanes according to the distance.

<The algorithm of distance calculation>

Step 1 : Calculate x_{left} and x_{right} using the obtained y_{car} as

$$x_{left} = \frac{y_{car} - b_{left}}{a_{left}},$$
$$x_{right} = \frac{y_{car} - b_{right}}{a_{right}}. \tag{2}$$

Then, compute the width W_{car} as

$$W_{car} = x_{right} - x_{left}. \tag{3}$$

Step 2 : For a pre-stored look-up table showing the relation between the actual distances and the y_{car} values as in Table II, calculate the widths using the equations in (2). The calculated widths are called W_i's.

Step 3: Compare W_{car} value with W_i values. Using two nearest W_i values, apply interpolation to find the distance corresponding to W_{car} value.

Table II
A Look-up table

distance	*y* values
5m	187
10m	123
15m	97
19m	84
23m	76
25m	73
30m	66
35m	62
40m	58
43m	57
45m	55
48m	54
50m	52
60m	48

The relative speed between the vehicles is calculated through t_{duration}, d_{previous}, and d_{present} as

$$v_{\text{relative}} = \frac{d_{\text{previous}} - d_{\text{present}}}{t_{\text{dulation}}}, \tag{4}$$

v_{relative} : relative speed between vehicles,
t_{duration} : time duration between frames,
d_{previous} : distance calculated via the previous frame,
d_{present} : distance calculated via the present frame.

Alarm is generated a few seconds in advance. The alarm generation time is calculated via v_{relative} and the speed of the driving car.

III. Algorithm Simulation

The simulation has been performed using low-cost 300K pixel camera for CCTV. Since the 256-gray-level image is used for the simulation, the specification of the camera meets the requirements of the simulation.

Figure 10 shows that the maximum error is less than 1 m within the range of 50 m and less than 4 m within the range of 70 m. Compared with the previous method [8], the proposed method makes the same errors within the range of 50m but can reduce the maximum error within the range of 70m. Figure 11 shows various test images with the detected y_{car} values.

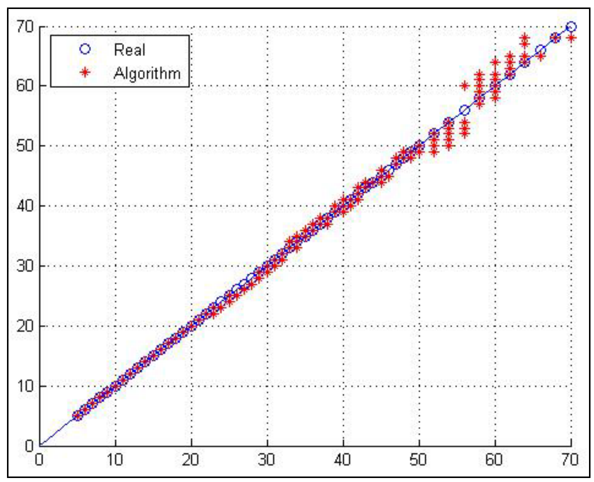
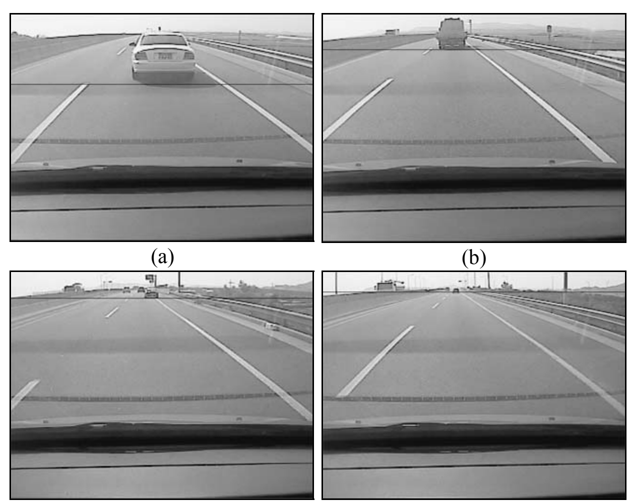


Fig 10. The accuracy of the distance calculation.



(a) (b) (c) (d)

Fig 11. Test images.

IV. SoC KIT IMPLEMENTATION

Figure 12 shows the SoC kit used to implement the algorithm. The kit consists of ARM EPXAnF1020C3, 32MB flash ROM, 256MB SDRAM, 512KB SRAM, 3.5" TFT-LCD, 16x2 Text LCD, and 14x10 Dot-matrix.

The 8-bit gray image data is converted to the Intel HEX format, and the Intel HEX format data is stored in the SDRAM.

The distance between the cars is calculated and displayed using the 7-segment. The processed image is displayed using the TFT-LCD. It is seen that the kit can process more than 15 images per second.

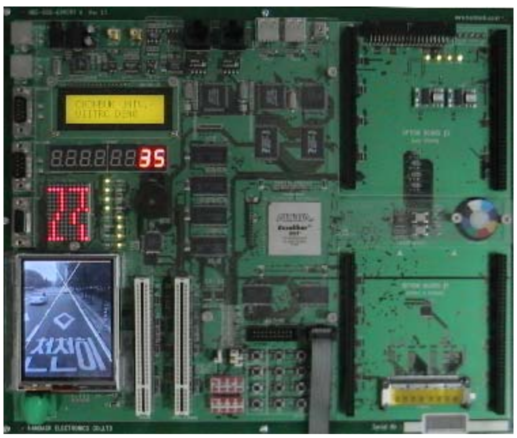


Fig 12. SoC kit.

V. CONCLUSIONS

This paper presented a method to detect the advance vehicle and calculate the distance between cars. Using the domain limitation, we can reduce the amount of the computation. It was shown that the distance between cars can be calculated more accurately using the information of the lane width obtained by a straight lane equation. By using a SoC kit, it was shown that the system can be efficiently implemented and operated in real time.

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