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RESEARCH ARTICLE

An Overview of Lane Departure Warning System Based On DSP for Smart Vehicles

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***Abstract*— This paper represents the lane departure warning system of smart vehicles based on real time camera implemented in a dual core DSP embedded system to verify the functionality. This system can be applicable for highways, roadways etc .The digital signal processor on lane departure system works with operating frequency of 600 MHz. The presented edge detection algorithm is efficient and robust at day and night.**

Sequences of images recorded with real time cameras mounted on moving vehicle gives information about the vehicle's environment to support the driver. Driver assistance system that monitors driver intent, warn drivers of lane departure, or assist in vehicle guidance are all being considered.

A DSP based lane departure system is equipped on the smart car, TAIWAN iTS, and has been successfully verified for hundreds of kilometres on Highway No.3 and Expressway No.68 in Taiwan. The developed system can reduce the complexity of vision data processing and meet the real time requirements.

Keywords*— *CAN; CCD; DSP; Lane Departure Warning System

I. INTRODUCTION

The increasing volume of automotive traffic requires higher level of traffic safety. In recent years, automotive traffic accidents stands fifth rank of first ten causes of death in India. Means more than thousands people were dead or injured in automotive accidents. During last decades lots of efforts has been taken to develop the intelligent driving assistance system to avoid accidents. With the help of this driver assistance system safety of automotives could be improved. A lane departure warning system is defined as system that warns the driver when an unintentional lane departure is about to occur. The aim of Intelligent Driving Assistance System is mainly that of increasing driving safety and reducing Drivers workload. This system can assist drivers to maintain proper driving within the lane and also warn to driver when vehicle is departing from current lane so that driver is alerted to take appropriate action. Lane departure warning system monitors the position of vehicle with respect to boundary. When the vehicle is in danger of leaving the lane unintentionally, for example, when the driver not paying full attention to the road ahead, the system delivers the warning to driver. An important component of a driver assistance system is evaluation of sequences of images recorded with real time camera mounted on moving vehicle. Sequence of images gives information about the automotive environment which has to be analysed to support the driver.

There are lots of lane departure warning system have been developed on different technologies. Cl´audio and Christa proposed a lane departure warning system that estimates lane orientation through linear parabolic model. B. Yu, W. Zhang and Y. Cai used a Gaussian template to remove the dirty spots in the image and dynamical threshold choosing to find lane marks. TLC and CCP method are used to make lane departure decision. P.Y. Hsiao, C. W. Yeh, S. S. Huang and L. C .Fu proposed an embedded ARM-based real-time LDWS. W. Zhu, F.

Liu, Z. Li, X. Wang and S. Zhang proposed an algorithm to choose a common curved lane parameter model which can describe both straight and curved lanes. N. M. Enache used composite Lyapunov Functions, polydral-like invariant sets and linear matrix inequality (LMI) method to implement the lane-departure avoidance system. M.J Jeng proposed a LDWS which is implemented in hardware and software. The hardware is implemented by FPGA. H. Y. Cheng proposed a method to utilize size, shape, and motion information to find the lane mark out. A .AM. Assidiq proposed a method to detect the lane mark by Canny edge detector and Hough Transform. J. F. Liu used gradient to find out the both lane marks.

The main purpose of this investigation is to implement a real-time lane detection algorithm and the vehicle position within the lane on the DSP-based image processor (DSP). This algorithm is also a prediction-verification-updating one with the modified model from 3D coordinate to image plane. Lane departure Warning System detects lane markings on the road and estimates the vehicle's position within its lane by using a monochromatic CCD camera with a 6mm lens in Fig. 1. The CCD is mounted behind the windshield on the experimental smart car, TAIWAN *i*TS-1, as shown in Fig. 2.

Fig. 1 Monocromic CCD camera

Fig. 2 TAIWAN *i*TS-1

The approach of this paper is extension of research by Bing-Fei Wu, and organized into 4 sections. The basic processing step is introduced in section 2. The DSP architecture is introduced in section 3. Section 4 presents the experimental results.

II. LANE DEPARTURE WARNING ALGORITHM

To improve previous work, a lane departure warning algorithm consisting of two parts, i.e., lane detection and lane departure detection, was proposed in this paper.

A. Lane detection

The purpose of the lane detection is to find the lane boundaries given by the currently observed image. Edge detection is a method of determining the discontinuities in gray level images. Edges are one of the most important elements in image analysis and processing in computer vision because they play quite a significant role in many applications of image processing particular for machine vision. However no edge detection algorithm can successfully discover edges for diverse images and no specific quantitative measure of the quality for edge detection is given at present.

Conventional edge detection Mechanisms examines image pixels for abrupt changes by comparing pixels with their neighbours. This is often done by detecting the maximal value of gradient such as Roberts, Prewitt, Sobel, Canny and so on all of which are classical edge detectors. The edges of image are considered to be most important image attributes that provide valuable information for human image perception. The edge detection is a terminology in image processing particularly in the areas of feature extraction to refer to algorithms which aim at identifying points in a digital image at which the image brightness changes sharply. The data of edge detection is very large so the speed of image processing is a difficult problem. DSP can overcome it. Sobel operator is commonly used in edge detection. Sobel operator has been researched for parallelism but Sobel operator locating complex edges are not accurate. It has been researched for the Sobel enhancement operator in order to locate the edge more accurate and less sensitive to noise but the software cannot meet the real-time requirement.

1. Sobel Edge Detection Enhancement Algorithm

The Sobel operator is a classic first order edge detection operator computing an approximation of the gradient of the image intensity function. At each point in the image the result of the Sobel operator is the corresponding norm of this gradient vector. The Sobel operator only considers the two orientations which are 0 and 90 degrees convolution kernels as shown in Fig. 3.

-1	0	1
-2	0	2
-1	0	1
Gx		

-1	-2	-1
0	0	0
1	2	1
Gy		

Fig.3 Sobel Operator

These kernels can then be combined together to find the absolute magnitude of the gradient at each point. The gradient magnitude is given by:

$$|G| = \sqrt{G_x^2 + G_y^2}$$

Typically an approximate magnitude is computed using:

$$|G| = |G_x| + |G_y|$$

This is much faster to compute. The sobel operator has the advantage of simplicity in calculation. But the accuracy is relatively low because it only used two convolution kernels to detect the edge of image.

2. Lane Departure Detection

In general, the dangerous lane departure situations result from the following two cases: 1) The driver gets too close toward the lane boundaries. 2) The host vehicle keeps a rapid departure speed, i.e., the host vehicle approaches the lane boundaries too fast. Therefore, we propose the spatial and temporal mechanisms to detect these two departure situations, respectively. Prior to detailing the warning mechanism, we introduce how to detect the vanishing point. The vanishing point is a point in the image plane to which a set of parallel lines in the 3-D space will converge.

Similar to the idea in, we use the vanishing point to automatically determine a warning box for lane departure warning and identify the region of interest to save processing time. To overcome the vehicle vibration and image noise suffered in, we find 50 vanishing points from the first 50 frames, respectively, and then use the statistical method to compute vanishing point *pv* = (*vx, vy*).

III. A DSP ARCHITECTURE

Lane detection warning is a typical computer vision process. Analyzing the relationship between data streams and information included in this data stream, we divide the vision process into two levels: the data process level and the symbol process level. The vision tasks in the data process level are characterized by a large data stream with simple operations, such as convolution, edge extraction, and line detection. By contrast, the vision tasks in the symbol process level are characterized by a small data stream with complex operations.

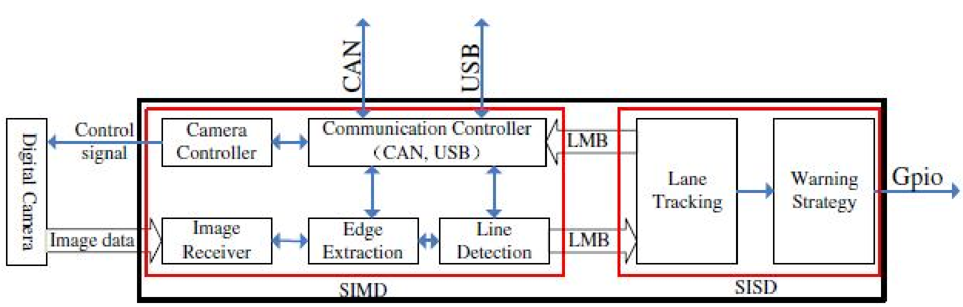

Fig.4 The architecture of the proposed LDWS

A. The flow of our system

The function, input and output sequences, and internal operations of the system are discussed as follows.

1. Camera controller unit

Our system uses a digital camera. In the camera controller unit, the automatic exposure control algorithm .Some parameters, such as exposure time and gain, are sent to the camera by serial peripheral interface bus. The others represent the camera's enable signal and required frame signal, among others.

2. Image receiver unit

This unit receives image data from the digital camera under line synchronic and frame synchronic signals. Eight-bit gray data are transmitted to the DSP based on a 40-MHz camera clock.

3. Edge extraction unit

This unit extracts an edge image from the original image using the vanishing point-based steerable filter. We use high-level information (the vanishing point) to obtain the orientation of the local features at each pixel. During edge extraction, each potential edge pixel of the lane should be directed toward the vanishing point. The details of this algorithm and its implementation on the DSP are described in Section 3.

4. Line detection unit

In this unit, a vanishing point-based parallel Hough transform is designed and implemented for line detection. When the edge image is extracted by the edge extraction unit, a Block RAM registers the position of a series of edge points. The edge image is unsuitable for calculation via a line equation because this equation requires x and y coordinates. The edge image, on the other hand, uses only binary information. We therefore store a list of edge positions instead of the edge image. To reduce computational complexity, we implement a parallel Hough transform in this unit. We move the coordinate origin of the Hough transform to the estimated vanishing point to reduce space complexity. During the Hough transform process, a series of double-port Block RAM are used as parameter storage.

5. Lane tracking unit

The lane tracking unit and the warning strategy unit are implemented in DSP core. A series of rules are set to remove disturbance lines, such as the vanishing point constraint and slope constraint. A simple algorithm similar to the Kalman filter is implemented for stable lane tracking. This unit employs a series of line parameters as input; the output is a pair of final lane parameters.

6 .Warning strategy unit

When double lanes are found, coordinate transform is carried out to determine the relationship between lanes and vehicle wheels. If a wheel crosses a lane, a warning message is sent.

7 .Communication controller unit

For easy and thorough system debugging and operation, we designed a controller area network (CAN) bus and a universal serial bus (USB). The USB is used primarily to debug the algorithm; an example is that the processed data is transmitted to a computer for debugging. The processed data include the original image data, edge image data, and all the line position parameters detected by our improved Hough transform.

The CAN bus is used mainly for receiving vehicle information (because CAN bus is widely used in vehicles), such as vehicle velocity and indicator information. The CAN bus is also used to send out warning signals from the LDWS, including those lane position parameters, distance between vehicles and lanes, and time spent crossing a lane. In addition, the CAN bus is used to enter the user's command instructions.

IV. RESULTS OF EXPERIMENTS ON ACTUAL ROADS

To test the system and its algorithms, we conducted numerous on-road experiments on a prototype device (Figure 5). The prototype works in different kinds of environments. The performance levels on urban roads, as well as under the presence of weak markings or disruptions by other vehicles are shown in Figure 5. Some challenging road conditions, such as wet weather, nighttime, and driving through a tunnel, is also depicted in Figure 5. The small cross in Figure 5 denotes the position of the vanishing point, and the circle around the vanishing point represents the parameter space range of $\rho = 4\sigma$, which is also the lane constraint, in which only the lines that go through the circle are detected. The warning time is tagged beside the marked lane; if it exceeds the previously established threshold, the alarm will be triggered. On-road testing was implemented both in an urban environment and on highways in Hunan province, China. Figure 14 shows the map of Changsha City. To complete our test, we chose an approximately 40-km highway and 16-km urban roads, denoted in green color in the figure. Testing on actual roads is dangerous for drivers because they are compelled to cross or change lanes without using turning signals, as required to determine whether the system works. Moreover, on-road testing is a difficult task, for whether it should give a warning is hard to tell, especially when the vehicle is driving along one side of the lane. To the best of our knowledge, no method to test an LDWS is available in on-road experiments for both the rate of failed alarms and the rate of false alarms. Here, 'failed alarm' means that the system does not issue a warning when it should, and 'false alarm' indicates that the system issues a warning when it is not supposed to.

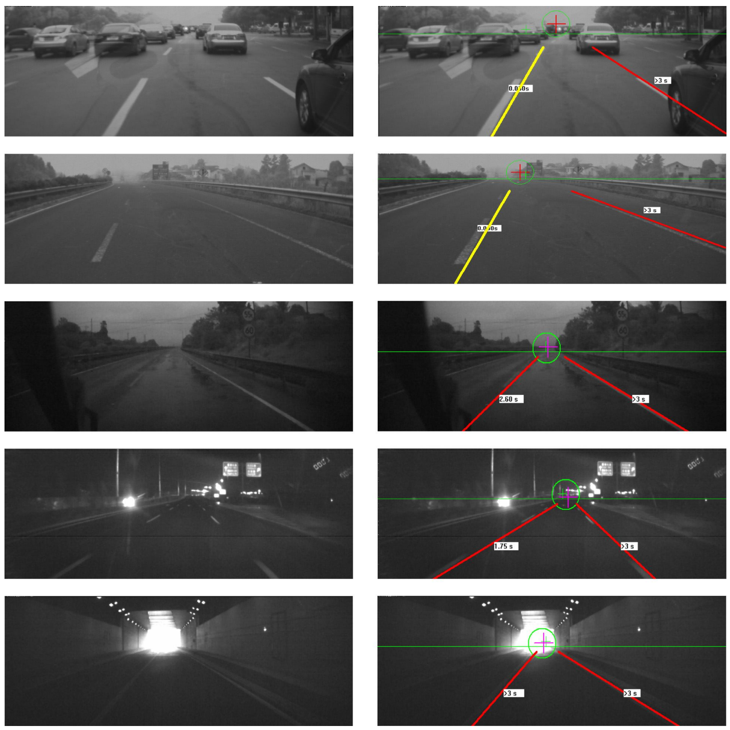

Fig.5 (a) Urban road and Vehicle disturbing (b) Worn off marks (c) Rainy (d) Night (e) Exit of a tunnel Original image tracking results

V. CONCLUSION

Lane Departure Warning System based on a DSP has been successfully implemented to serve drivers for their unintentional lane departure. It is also equipped on TAIWAN *i*TS-1 for hundreds of kilometers verification on Highway No. 3 and Expressway No. 68 in Taiwan. The proposed lane detection algorithm ie sobel works well under different weather conditions in day and night. Different types of lane marking in straight or curve lanes won't influence the performance of departure warning. Future work will concentrate on studying the vision-based vehicle detection and distance estimation to warn the drivers when the vehicle and the previous car are too close. Certainly, this will be integrated on the DSPIP to extend the functions of lane departure warning system.

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