International Journal of Advance Research in Engineering, Science & Technology(IJAREST),
ISSN(O):2393-9877, ISSN(P): 2394-2444,
Volume 2,Issue 5, May- 2015, Impact Factor: 2.125

Survey on Blind Spot Detection and Lane Departure Warning Systems

Prof.Arun Tigadi[1], Prof.Rudrappa B. Gujanatti[2], Rohini Patil[3]

[1]Electronics and Communication, KLE'sDr. M S Sheshgiri College of Engineering and Technology, arun.tigadi@gmail.com

[2]Electronics and Communication, KLE's Dr.M S Sheshgiri College of Engineering and Technology, rudraguj@gmail.com

[3]Electronics and Communication, KLE's Dr.M S Sheshgiri College of Engineering and Technology, rohinispatil@gmail.com

Abstract:
The goal of this paper is to propose a solution to improve a driver's safety while changing lanes on the highway in intelligent vehicle applications. In fact, if the driver is not aware of the presence of a vehicle beside his vehicle a crash can occur. Blind Spot Detection System and Lane Departure Warning System are the two components of Advanced Driver Assistance System (ADAS).These two components monitors and warn drivers of lane departure, or assist in vehicle guidance which may be present in the blind spot area. The blind spot system uses radar based technology and camera based technology. A camera is mounted in the lateral mirror of a car with the intention of visually detecting cars that cannot be perceived by the vehicle driver since they are located in the so-called blind spot and the radar is used to calculate the distance of the object from the host vehicle. The Lane Departure System uses particle filter-based approach. This model parameterizes the relationship between points of left and right lane boundaries, and can be used to detect all types of lanes .A modified version of an Euclidean distance transform is applied on an edge map to provide information for boundary point detection

Keywords- *Blind spot, Radar Sensor, Infrared Sensor, Camera, DSP, Ultrasonic based BSD*

I. INTRODUCTION

Car accidents on the highways are a big factor of mortality and can cause severe injuries. Actually, drivers nowadays are getting more concerned about safety features in their cars and thus are willing to pay the cost of acquiring safer vehicles. Motivated by economic factors, a new research domain has thus emerged in the recent years. With the help of this driver assistance system safety of automotive could be improved. An ADAS consists of environment sensors and control systems to improve driving comfort and traffic safety by warning the driver or even autonomous control of actuators. The main threat for a driver on the highway comes from the surrounding cars especially when he is not aware of their close presence. This can be managed by two of the ADAS components-Blind Spot Detection System and Lane Departure Warning System. In fact one of the main features of an onboard car safety system is to detect the presence of a close car in the driver's blind spot (Figure 1) and warn the latter about it. This information can help the driver in a lane change situation and affect his decision to perform this task. Blind Spot is defined as an area around the vehicle that cannot be directly observed by the driver while at the controls, under existing circumstances. This exist in a wide range of vehicles: cars, trucks, motorboats, sailboats and aircraft.

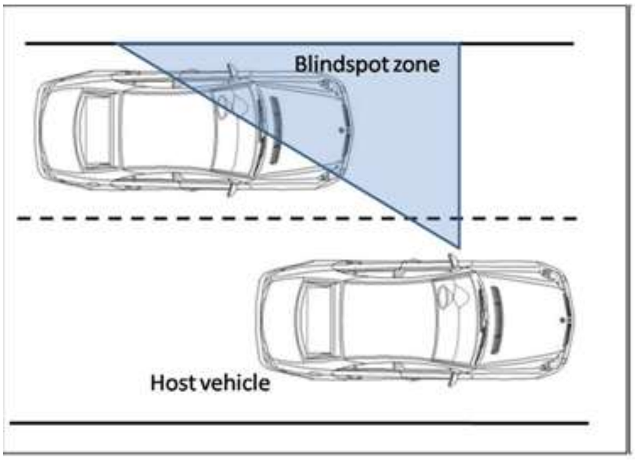

Figure 1: The blind spot zone description: We define the blind spot of a driver as the zone he cannot see through his side and rear view mirrors.

A lane departure warning system is defined as system that warns the driver when an unintentional lane departure is about to occur. These systems are designed to minimize accidents by addressing the main causes of collisions: driver error, distractions and drowsiness. 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 analyzed to support the driver.
The most common LDW system is a camera mounted high up in the windshield. It captures a moving view of the road ahead. The digitized image is parsed for straight or dashed lines. Camera captures images of road that image is further processed to detect lane and make decision depending upon car position. As the car deviates and approaches or reaches the lane marking, the driver gets a warning: a visual alert plus either an

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audible tone, a vibration in the steering wheel, or a vibration in the seat.

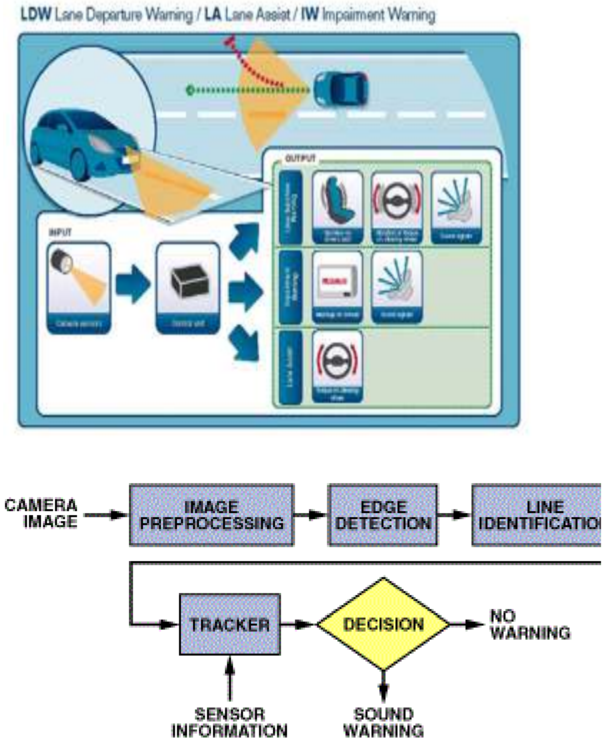

***Figure 2**: LDW*

II. TYPES

1. TYPES OF BSD

Every auto manufacturers approaches the problem of blind spot detection in slightly different way, but we can loosely group the new blind spot monitoring technologies into two different categories: Active and Passive.

A. ACTIVE BLIND SPOT MONITORING

This uses some kind of electronic detection device(s). Based on this there are two types: Camera based : In this camera is mounted on the sides of the car often in the vicinity of the external rear view mirrors to capture images. Radar based : radar sensor is present near the rare bumpers that send out electronic electromagnetic waves(usually in the radar wavelengths) to calculate distance of the vehicle from the host vehicle.[1]

***Figure 3**: Radar based BSD and Camera based BSD*

B. PASSIVE BLIND SPOT MONITORING

There are no electronic devices used in this. Only convex mirrors are used on door side that can see into areas where normal rearview mirrors cannot.

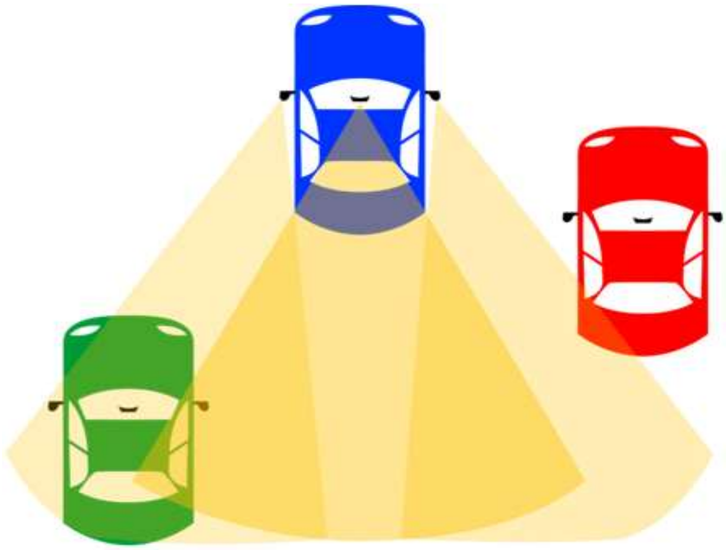

***Figure4**: Passive blind spot*
The blue car's driver sees the green car through his mirrors but can't see the red car without turning to check his blind spot (the mirrors are not properly adjusted).

2. TYPES OF LDW SYSTEM

There are two main types of systems:
Systems which warn the driver (lane departure warning, LDW) if the vehicle is leaving its lane (visual, audible, and/or vibration warnings)
. Systems which warn the driver and, if no action is taken, automatically take steps to ensure the vehicle stays in its lane (lane keeping system, LKS)

Different technologies have been utilized to create LDW systems. There are currently two types of LDW systems that have been introduced to the market. A camera based system and an infra-red system.

The typical camera-based LDW system utilizes a forward-looking camera mounted behind the windscreen that continuously tracks visible lane markings. This is linked to a computer with image recognition software that may also compute inputs for vehicle information such as speed, yaw rate, and steering angle. Camera-based LDW systems rely on the lines painted on the roadway to calculate the lateral divergence and divergence angle from the lane's centre. It then estimates the future vehicle position through sophisticated algorithms. If the data suggests that the vehicle is leaving its intended path unintentionally, the system alerts the driver.

An infrared-based LDW system uses a series of infra-red light sensors mounted under the front bumper of the vehicle to identify the lane markings on the road- way. Each sensor contains an infra-red light-emitting diode and a detection cell. The sensors detect the variations in the reactions from the infra-red beams emitted by the diode onto the road. When the vehicle moves over a lane marking the system detects a change and alerts the driver if the indicator signal has not been used.

III. BLOCK DIAGRAM FOR LDW

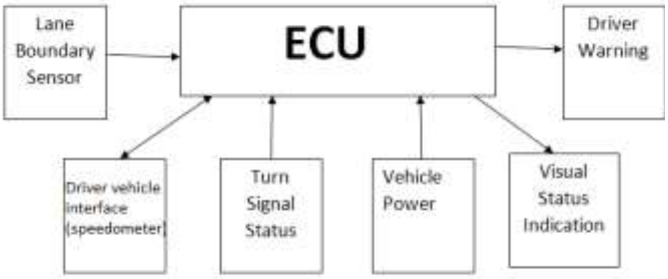

Figure 4: LDW SYSTEM

Sensors:
Vehicle speed sensor, optical or infrared image sensor, turn signal sensor
Actuators:
Audible warning alarm, visual indicator, steering wheel vibrator
Data Communications:
. Communication with ECM: CAN bus
. Image sensor communication: AV IN *4
. Control Panel (LCD) communication: NTSC/12C

IV. LANE DETECTION

A. A NEW LANE MODEL

The lane model used in the here is illustrated, the 3D view also contains the x y-coordinate system in the ground manifold. Here we assume a ground plane.[4]

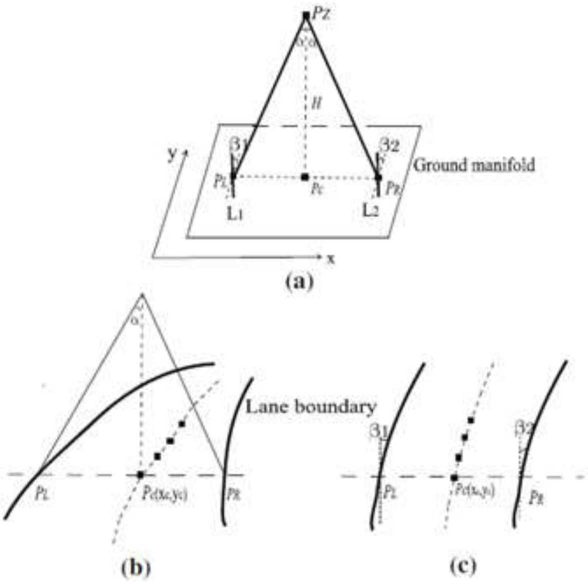

Figure 5: Lane model as used in this paper a. 3D lane view; boundaries are drawn in bold b. Perspective 2D lane view in the input image c. Bird's-eye image of the lane. Slope angles β1 and β2 are shown in the 3D view and the bird's-eye image; the zenith angle α in the 3D and the projective view.

(Wedel proposes cubic B-splines for modeling the ground manifold.)Five parameters xc, yc, α, β1, and β2 are used to model opposite points PL and PR, located on the left and right lane boundaries, respectively. PC = (Xc; Yc) is the centerline point of a lane in the ground plane. α is the zenith angle above PC, defined by an upward straight line segment between PC and the zenith PZ of fixed length H, and a line incident with PZ and either PL or PR. As the height H is fixed, the width of a lane W at points PL and PR can be easily calculated as
W = 2H *tan (α)
β1 and β2 are the slope angles between short line segments L1and L2 and a vertical line in the ground plane; the two Short line segments L1 and L2 are defined by a fixed length and local approximations to edges at lane boundaries (e.g., calculated during point tracking). Ideally, L1 and L2 should coincide with tangents on lane boundaries at points PL and PR; in such an ideal case, β1 and β2 would be the angles between tangential directions of lane boundaries at those points and a vertical line. By applying this model, a lane is identified by two lane boundaries, and points are tracked along those boundaries in the bird's-eye image. As β1 and β2 are calculated separately, a lane may also have an unparallel left and right boundary.

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. Conventional edge detection Mechanisms examines image pixels for abrupt changes by comparing pixels with their neighbors. 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 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. 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.

B. SOBEL EDGE DETECTION ENHANCEMENT ALGORITHM

The Sobel operator is a first order edge detection operator computing an approximation of the gradient of the image intensity function .An image gradient is a directional change in the intensity or color in an image. Image gradients may be used to extract information from images. The gradient of a two-variable function (here the image intensity function) at each image point is a 2D vector with the components given by the derivatives in the horizontal and vertical directions. At each image point, the gradient vector points in the direction of largest possible intensity increase, and the length of the gradient vector corresponds to the rate of change in that direction. At each point in the image the result of the Sobel operator is the corresponding norm of this gradient vector. The most common way to approximate the image gradient is to convolve an image with a kernel, such as the Sobel operator. 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.6

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

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

Figure6. 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:

$|G| = \sqrt{(Gx2 + Gy2)}$

Typically an approximate magnitude is computed using:

$|G| = |Gx|+|Gy|$

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 kernel to detect the edge of image

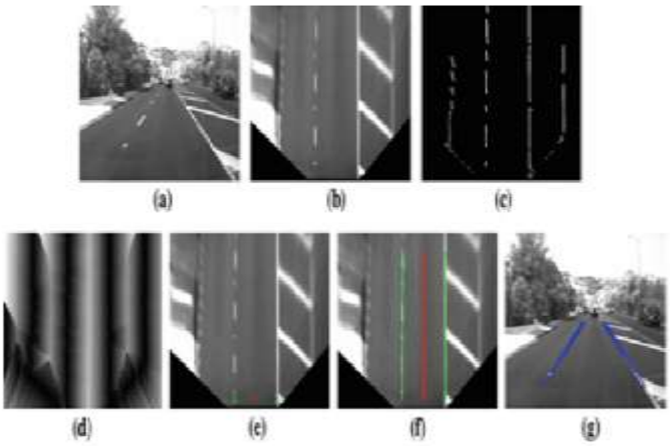

Figure 7**: **The overall work flow of lane detection. a Input image. b. Bird's-eye image. c. Edge map. d. Distance transform. e. Initialization. f Lane detection results, shown in the bird's-eye image. g Lane detection results, shown in the input image

C. IMAGE PROCESSING:

Low-level image processing is composed of three steps:
1. Bird's-eye mapping
2. Edge detection and de-noising
3. Distance transform.

1. BIRD'S-EYE MAPPING: As in a four-point correspondence is used for the mapping from an input image into a bird's-eye image. The mapping is achieved by selecting four points when calibrating the camera, and using the locally planar ground manifold. One benefit of the bird's-eye image is that the used distance scale can be adjusted by selecting different sets of four corresponding points. Also, lane marks in the bird's-eye image have a constant width, which will be utilized for edge detection.

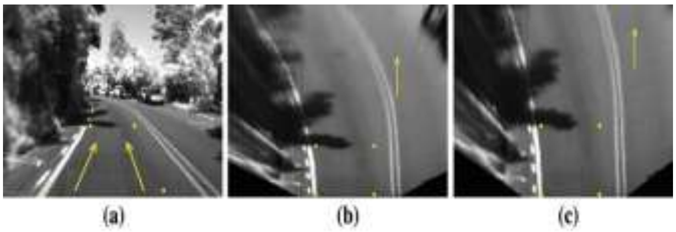

Figure 8: a. Input Image b. and c. are bird's-eye images based on different distance definitions. Four-point correspondence (points shown in yellow) is established by calibration; the driving direction is indicated by the arrows

2. EDGE DETECTION AND NOISE REMOVAL*:* We recall an edge detection method as introduced. Vertical edges with black–white–black pattern are detected in the bird's-eye image by a specially designed simple algorithm. Every pixel in the bird's-eye image, with value b(x; y), is compared to values b(x- m; y) and b(x+ m; y) of its horizontal left and right neighbors at a distance $m \geq 1$ as follows:

$B + m(x; y) = b(x; y) - b(x + m; y)$

$B - m(x; y) = b(x; y) - b(x - m; y)$

And finally, using a threshold T , the edge map value will be

$r(x; y) = \{1 ,\ \text{if } B + m; B - m > 0; B + m + B - m \geq T$

$0 ,\ \text{otherwise}\}$

This edge detection method has the following properties.

a. m can be adjusted to fit various width of lane marks.
b. Pixels within a lane mark are all labeled as being edge pixels, which is different from gradient-based edge operators (e.g. Canny, Sobel). This greatly improves the robustness in detecting points of lane marks.
c. Shadows on the road surface do not influence edge detection at lane marks. In the presence of shadows, the brightness of lane marks may be affected, but generally it will still maintain superiority relationship with their horizontal neighbors. Thus, the edge detection method can be used under different illumination conditions. Finally, horizontal edges (unlikely to be lane marks) are not detected.

The edge detection as introduced above may generate some isolated small blobs (including single point) besides the edges of real lane marks. These noisy blobs will greatly affect the result of the following distance transform. In order to remove such noise, a specified operation is applied. The general idea is first to find the isolated blobs, and then set them to zero (non-edge). Two small square windows (inner and outer) are used with the same center. And the outer window is larger in width with a gap of 1 pixel than the inner window. The isolated blobs can be detected by moving at the same time these two windows through the whole edge map, and comparing the sums of edge values within them. Two equal sums means that the gap between two windows contains no edge points, and the edge blobs in the inner window are detected as isolated and set to zero. For computational efficiency, an integral image of the edge map is used to calculate the sums inside small windows.

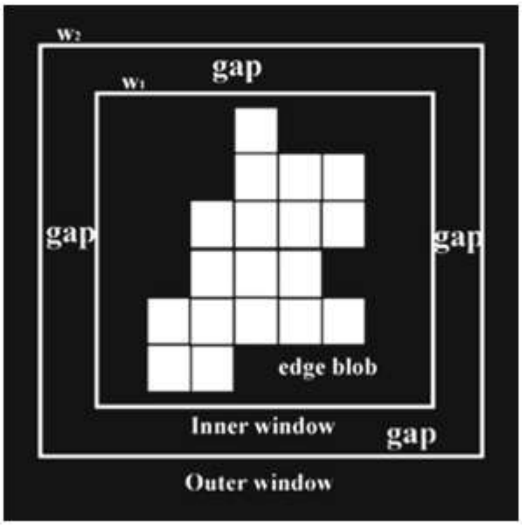

Figure 9: Detection of the isolated blobs in the binarized edge map. The square inner window and outer window with a gap of 1 pixel (w2- w1 = 2) move at the same time through the edge map. When the gap between the inner and outer window contains no edge, an isolated blob is detected in the inner window.

3. DISTANCE TRANSFORM

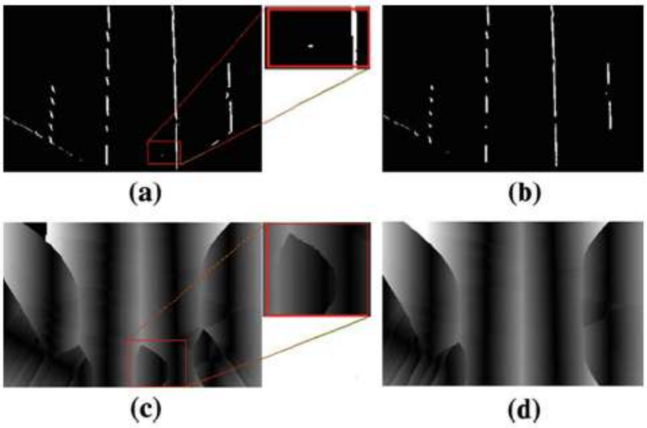

***Figure 10**: Effect of isolated noisy point in edge map for distance transform. a. Noisy edge map with an isolated edge point in the middle of lane. b De-noised edge map. c RODT of (a). (d) RODT of (b)*

Distance transform applied to a binary edge map I labels each pixel with distance to the nearest edge pixel. For all pixels p of I, distance transform determines.

$dt(p) = \min_u\{d(p; q_u) : I(q_u) = 0 \wedge 1 \leq u \leq U\}$ (1)

Where $d(p; q_u)$ denotes a metric, and u lists all U pixels in the image I . The values for dt(p) depend on the chosen metric. Edges are obviously labeled by value 0, and shown as black in the generated distance map. Among various distance transform, Euclidean distance transform (EDT) is a common choice. The original EDT uses Euclidean metric for measuring the distance between pixels. We substitute $d(p; q_u)$ in Eq. 1 by the Euclidean metric $d_e(p; q_u)$ as follows:

$d_e(p; q) = \sqrt{(x1 - x2)^2 + (y1 - y2)^2}$ (2)

for points p = (x1; y1) and q = (x2; y2).

Felzenszwalb proved that a 2D EDT can be calculated by two 1D EDTs, and this greatly improves the computational efficiency. A modified EDT is even called as Orientation Distance Transform (ODT). This divides the Euclidean distance into two contributing components in row and column direction.

(Note that the use of a four- or eight-distance transform would not lead to the same row and column components; however, practically there should not be a big difference with respect to the given context.) The row part of ODT, named as RODT, labels each pixel with a distance value to the nearest edge point in row direction. Moreover, RODT is signed, with a positive value indicating that the nearest edge point lies to the right, and a negative value if it is to the left. The RODT of an edge map offers various benefits. Generally, as a distance transform, every pixel in RODT map indicates where its nearest edge point is. Thus, more information about a lane (e.g. information of the centerline or road boundary) is provided by distance transform when compared with edge map. For example, a (non-edge) pixel on the centerline of a lane will have a local maximum in distance to lane boundaries. This information is of great usefulness to find or go towards edge points, and will be fully utilized in lane detection and tracking methods introduced in the following sections. Moreover, compared with EDT, RODT brings several advantageous properties in lane detection situation. First, the initialization of lane detection becomes much easier. Second, discontinuous lane marks will make almost no difference from continuous ones in RODT, but not true in EDT, This also provides algorithms the ability to find the approaching lanes in advance. Distance transform is sensitive to some isolated points or blobs in lane detection situation. As indicated in Figure, an edge point in the middle of a lane will greatly change the distance value for the surrounding pixels. So a de-noising method on the edge map as introduced, and proves to be useful.

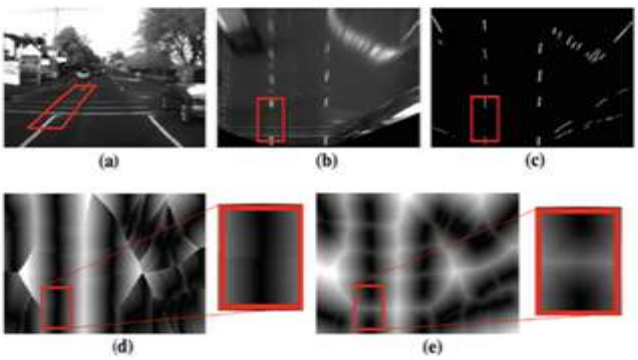

***Figure 11**: EDT and RODT on discontinuous lane marks. a. Road image b. Bird's-eye view.*
c. Binarized edge map after noise removal. d RODT. e EDT. d, e have been contrast adjusted for better visibility.
Note RODT shows no gap for the discontinuous lane marks inside the rectangle, while EDT still contains some gap

V. LANE TRACKING

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Lane tracking uses information from the previous results to facilitate the current detection. There are two aims to utilize the previous information: one is to improve computational efficiency of the current detection from a prior knowledge; another is for robustness. Generally, lane detection in some situations will be relatively easier as compared to others, depending on road conditions and quality of lane marks. For these reason, there are two lane tracking methods:[4]

a) Efficient lane tracking
b) Robust lane tracking

Efficient lane tracking:
Efficient lane tracking method is fit to situations characterized by good road conditions and good quality of lane marks (such as driving on a highway). It simply uses previously detected lane boundary points, adjusts them by the ego vehicle's motion model, and then refines them according to the distance values from RODT on the current bird's-eye edge map.

Robust lane tracking:
Urban roads differ from highways by an increased complexity of environments possibly of relevance for accurate lane detection. In such situations, robustness lane tracking is of dominant importance.

VI. LANE DEPARTURE METHOD

The new proposed methodology for lane departure indication is as described. ROI of an image is extracted and represented as Ri. Edges in an image are detected using Hough transform. Hough origin Ho is placed at the coordinate (x/2 ,0) . Edges of lanes are extracted. Left edge mid-point and right edge mid-point viz. M L , M R is calculated. A line joining from each mid-point to Hough origin is plotted and its length is measured as KL , KR . Also, horizontal distance between the mid-points is noted down as length C shown in fig.[5]

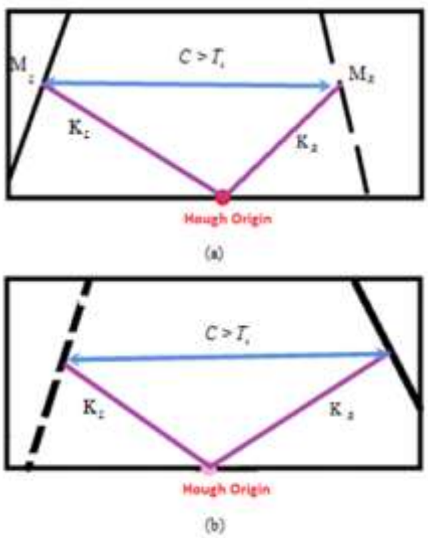
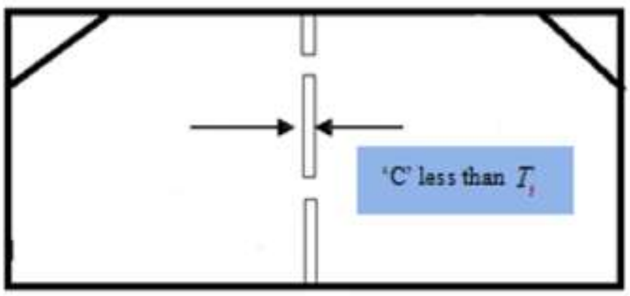


Figure 12: New Lane Departure Calculation (a) Left departure, (b) Right departure

If the value of length C is greater than initial threshold Value Ti then the position of car will be examined for departure. The terms KL, KR are used to obtain information in this regard. As shown in above figure, if length KR is less than KL then car is near right lane otherwise if length KR is greater than KL then car is near left lane. The initial thresholds for minimum lengths are set. If either of the length KL, KR reduces below some threshold TL, TR then lane departure on left side or right side occurs and necessary warning will be given to driver. The algorithm for proposed lane departure method is given in following pseudo code.

```
IF MID-POINTS CALCULATED || IF C > T_i
    IF K_R < K_L && IF K_R <
                T_R
      WARNING: RIGHT DEPARTURE
    ELSEIF K_L < K_R && K_L <
                T_L
      WARNING: LEFT DEPARTURE
   ELSEIF K_L = K_R
            NO ACTION;
            CAR IS IN LANE
  ELSEIF C < T_i
            WARNING: LANE CROSSING
  ELSE
            NO LINE DETECTED
  END
```

On the contrary, if the value of C is lesser than initial threshold value Ti , as shown in Figure , car is crossing the lane and is on the central axis of the road



As shown in this Figure, dotted lane marking is identified. Edges are extracted with outer boundaries. The length C is the distance between the edges shown in figure. C is always less than the initial threshold value in case when car is in left or right lane. During left or right departure, C is always greater than initial threshold. ROI segmentation is taken into account. The uniqueness of the algorithm lies in considering value of C as shown in Figure. Three cases are assumed:

Case I:

C is greater than initial threshold value Ti when left departure occurs – In this case, the value of C is greater than 50. The length KL, KR is calculated. Centroid of KL, KR is estimated which decides C value. For left departure, KL < KR is condition is satisfied.

Case II:

C is s greater than initial threshold value Ti when right departure occurs - In this case, the value of C is greater than 50. For left departure, KR < KL condition is satisfied.

Case III:

C is less than initial threshold value Ti - In this case C value is less than 50. Car is crossing the lane.

VII. A DSP ARCHITECTURE FOR LDW

Lane detection warning is a typical computer vision process. Analyzing the relationship between data streams and information included in this data stream, the vision process can be divided into in to 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.[5]

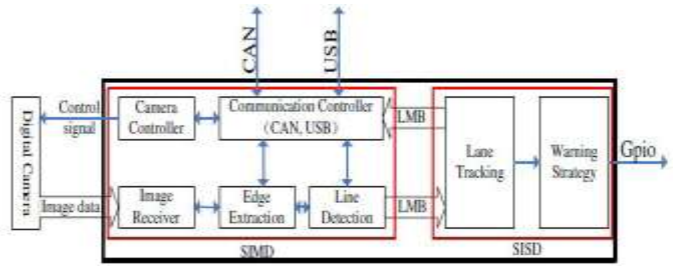


Figure 13*: *The architecture of the proposed LDWS

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
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 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.

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.

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. This unit employs a series of line parameters as input; the output is a pair of _nal 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, a controller area network (CAN) bus and a universal serial bus (USB) is present. The USB is used primarily to debug the algorithm. 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, 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.

VIII. TYPICAL BSD SYSTEMS

1) TYPICAL ULTRASONIC BASED BSD

Ultrasonic sensor system The general architecture of automobile ultrasonic systems is shown. It consists of the ultrasonic sensors mounted into the front and rear bumpers, the analog amplifiers and filters and the ECU. The main unit of the ECU (generally a microcontroller) generates the signal and drives the sensors by the power amplifier. The generated sound waves reflect of an object and are converted back to electronic signal with the same sensor element. The MCU measures the eco signal, evaluates and calculates the distances. Generally the results are broadcasted by high level communication interface such as CAN, sent directly to an HMI for further processing.[2]

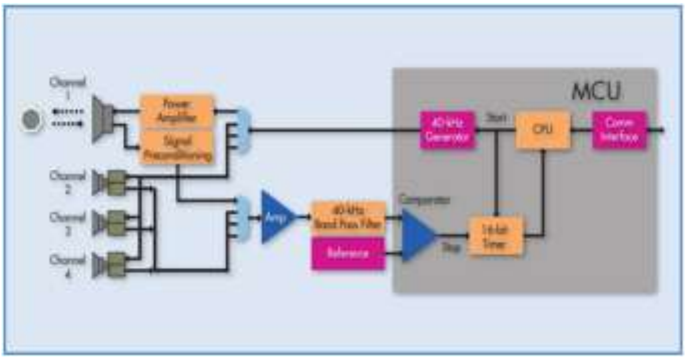


Figure 14: Ultrasonic based BSD

2) TYPICAL CAMERA BASED BSD

The camera captures images of the object in blind spot area into 8 consecutive frames for analysis. The processing involves the selection of certain pixels in an image of one frame and comparing them with the other frames. If the object is stationary, then the position of pixels in the 8 consecutive frames relatively remains same or vanishes after 2-3 frames. This concludes that the object is stationary and it can be dropped. If the object is moving then the position of the pixels in the consecutive 8 frames relatively vary and thus we can conclude that the object is moving and it can be indicated to the driver.

IX. DRIVER ALERTS

Whenever any vehicle comes in the blind spot area the driver is made alert by lighting up the yellow or red LEDs on the door side and if the driver switches on a lane change indicator while the blind spot object warning lights are on , the LED become brighter and starts to _ash. This can also be followed by audio alerts. In some systems, driver is warned by vibrating the seat belt or stirring wheel.
LDWS may also help prevent rollover crashes. For example, if the vehicle drifts out of the lane onto the shoulder, the car could roll over if a sudden recovery maneuver is made. In addition, a car may roll over due to any recovery maneuver involving a high lateral velocity (rate of departure), requiring a relative large amplitude and/or rapid steering action.[3]

Figure 15**: **Driver Alerts

X. ADVANTAGES

- Accidents can be avoided.
- Changing of lane will be easier and safe.
- If you have blind spot detection, the sensors may also provide cross traffic alert.
- LDWS may also help prevent rollover crashes. For example, if the vehicle drifts out of the lane onto the shoulder, the car could roll over if a sudden recovery maneuver is made. In addition, a car may roll over due to any recovery maneuver involving a high lateral velocity (rate of departure), requiring a relative large amplitude and/or rapid steering action.

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