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Three Dimensional Surround View System

Shashikant Chavan
Dept. of Electronics and Telecommunication
MITCOE, Pune, India
Prof. Dr. V.V. Shete
Dept. of Electronics and Telecommunication
MITCOE, Pune, India

ABSTRACT: The evolving automotive ADAS (Advanced Driver Assistance System) technology is consist of automotive surround view camera system on a vehicle . The automotive surround view camera system assists the driver during drive the vehicle. The system is providing 360 ^{0}view around the vehicle by using four (fish eye lens) cameras attached around the vehicle, each covering a different direction .The camera calibration method use to produce inverseprospectivemapping of undistorted images onto 3D bowl model, stitched those images on bowl geometry ,and then rendered those images as third person point of view selected by the driver. This system is use to remove blind spot problem during the drive the vehicle. The system runs real time on DSP C66x producing surround view around vehicle.

Keywords: ADAS; Inverse Prospective Mapping; TDA2X; OpenCV;OpenGL; vision SDK.

INTRODUCTION

One of the major reasons causing car accidents are because of blind spot present around the vehicle. The main goal of advanced driver assistance system is helping driver to observe situation everywhere around the vehicle. Toward achieve this goal , many types of ADAS have been developed. For example , the distance of obstacles are measure by parking sensors from the vehicles and beepers are use to warn the drivers. Rear view camera shows the vehicle from behind and can help drivers to drive backward. The prices of cameras are keep dropping because of that practically to mount more number of cameras around the vehicle to provide drivers with vehicle surrounding views.

[7]Liu, Lin and Chen proposed a system with mounted of six fisheye cameras around the vehicle and provide a bird eye view of all stitched six images together to form vehicle surrounding environments. In their method, they have applied one dimensional stitching to solve the discontinuity issue on a overlap area. [8] Ehlgen and Pajdla proposed a system of four omnidirectional cameras around a truck. They established some way to split the overlap area delivered a bird’s eye view image. But their final integrated results are discontinuous on the overlap between different cameras. [5] Nissan developed an advanced driver assistant system which can render four images from wide angle cameras to form surrounding view of vehicle. This system is able to provide drivers with both the bird eye view and original images captured by four cameras. The Eagle eye view in addition of 360 degree surround imaging system from Luxgen and new multi view camera system developed by Honda used same approaches to afford drivers much better visual awareness of surroundings. These two systems were able to project the captured and undistorted images onto a ground plane and keep four black overlap region between adjacent cameras.[6] Fujitsu released 360 degree wrap around video imaging technology ,which enables free eye point viewing onto a 3D curved plane.

The three dimensional surround view system play an important role in assisting drivers during parking, traffic safety and maneuvering the vehicle. This type of system are used for long variety of trucks, tractors, personal vehicles and even larger ships and boat. Here our focus on an implementation of three dimensional view system for personal vehicles. In this paper we propose a real time monitoring system for driver assistance. The proposed system consists of four fish eye cameras mounted on the vehicle. The out of four cameras ,one

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camera placed on the front of vehicle, another one on rear of the vehicle, and remaining ones are on the left and right side view mirrors. Each camera is connected to hardware unit, which is responsible for image capturing ,image warping on proposed bowl model, blending of images from each camera. The camera calibration process plays an important role in forming surround view system. Here we applied Zhang's method to evaluate the intrinsic parameters of each camera. Extrinsic parameter of each camera were calculate for homographic transformation. Finally, with the help of inverse prospective mapping on the hybrid model form a driver selected viewpoint system.

3D BOWL GEOMETRY MODEL

The two Dimensional view system formed by using render the images on ground plane. When four camera images stitched on flat ground plane then it has difficult to find out an obstacle or pedestrian present near vehicle. It was also difficult to find out blind spot area near vehicle. So by considering above two main disadvantage of two dimensional surround view system, we looked forward forThree dimensional surround view system in this paper.

Three dimensional view gives depth in camera capture images which look like real world present around the vehicle. These three dimensional view must form on three dimensional hybrid model. Here we choose three dimensional mesh bowl geometry as a 3D hybrid model. These 3D mesh bowl geometry can form with the help of graphics libraries which is supported by hardware (which we used in our paper). Now, 3D bowl geometry become mapping plane instead of ground plane. The whole mesh grid geometry covers four camera image mapping with the help of camera calibration process, look up table and blending. Finally, with the help of 3D mesh grid geometry our system able to form 360 degree view around the vehicle. The 3D bowl geometry is shown in figure 1.

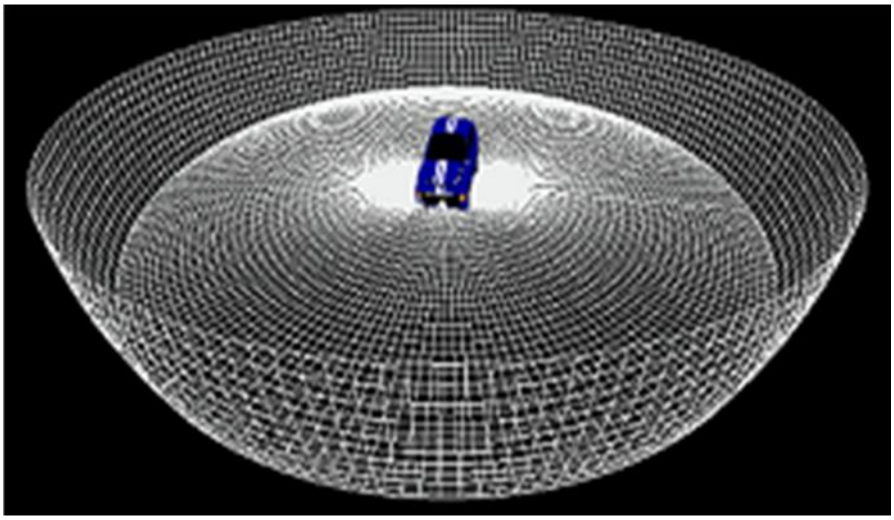

Fig 1. 3D Bowl Mesh Geometry

CAMERA CALIBRATION

The fish eye camera lens has FOV (field of view) of 180 degrees. Which is able to cover the whole hemispherical field in front of the camera. It is impossible to maps the hemispherical field of view on a finite image plane by a perspective mapping .The perspective mapping is basically transformed of 3D world coordinates to the 2D image coordinates. In 3D surround view , The 2D image plane have to map on 3D bowl geometry plane which called as inverse perspective mapping. The inverse perspective mapping applied on four camera images with the help of camera calibration process.

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The main objective of camera calibration is to determine a different set of camera calibration parameters that are use for mapping between 3D reference coordinates and 2D image coordinates. The camera calibration parameters are commonly divided into extrinsic and intrinsic parameters.

A. InteinsicParametres

The intrinsic parameters of camera commonly include the effective focal length, scale factor and principal point also called image center. Here we followed the standard procedure of Zhang's camera calibration method, we made a chess board as a camera calibration pattern and took multiple images with the chess board pattern in different poses and position. Each camera may have different focal length so we have to follow same Zhang's method for existing four camera. Finally, weobtained intrinsic parameters of camera by using the OpenCv procedure of Zhang's method.

The intrinsic matrix (Mi) is given below,

$$\text{Mi}= \begin{bmatrix} f & 0 & c \\ 0 & f & c \\ 0 & 0 & 1 \end{bmatrix} \qquad (1)$$

Where, equation (1) consist of fx,fy as a focal length in pixel and cx, cy as a principal point of camera.

HOMOGRAPHY TRANSFORMATION AND EXTRINSIC PARAMETERS

A. Homoghraphy Transformation

After fish eye camera calibration process, the next step is to stitch four fish eye camera images to form a vehicle surrounding view. The four fisheye camera captured images toward front, back, left and right direction around the vehicle. To stitch four images, we use the homography transformation to map camera images onto a reference bowl geometry plane. The homographytransformation consist of intrinsic and extrinsic parameters of camera.

The inverse prospective is possible due to homography matrix. The homoghraphy matrix (H) equation is given below,

$$\text{H}= \begin{bmatrix} H1 & H2 & H3 \\ H4 & H5 & H6 \\ H7 & H8 & H9 \end{bmatrix} \qquad (2)$$

The corresponds between image point and 3d world point is given below,

$$Xc = H\ Xw \qquad (3)$$

Where, equation (3) consist of Xc is image co-ordinate system and Xw is world co-ordinate system.

B. Extrinsic Parameters

If obtain the homography transformation matrix then we can know the relationship between 3D geometry plane and each fish eye image. The extrinsic parameters of camera consist of rotational matrix(R) and translational vector(T).The extrinsic parameters, which represent the coordinate system transformation from 3D world coordinate system to 3D camera coordinate system, are calculated by the following equations ,

$$\text{Me}= [R1 \quad R2 \quad R3 \quad T] \qquad (4)$$

$$\text{H}=[H1 \quad H2 \quad H3] = S \,.\, Mi\, [\,R1 \quad R2 \quad T\,] \qquad (5)$$

$$R1=\frac{1}{S} \,.\, M_i^{-1} \,.\, H1 \qquad (6)$$

$$R2=\frac{1}{S} \,.\, M_i^{-1} \,.\, H2 \qquad (7)$$

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$$T = \frac{1}{s} \cdot M_i^{-1} \cdot H3 \quad (8)$$

and

$$R3 = R1 \text{ X } R2 \qquad (9)$$

Where, equation (5) is consist of H1,H2,H3 are the column of homographic matrix(H), equation (5),(6) (7) and (8) consist of S is showing scaling factor, equation (4) is consist of Me is extrinsic matrix ,which is form with the help of Rotational matrix(R) and Translation matrix(T).

The rotational matrix(R) is given below,

$$\text{Rx}=\begin{bmatrix} 1 & 0 & 0 \\ 0 & c & -s \\ 0 & s & co \end{bmatrix} \quad (10)$$

$$\text{Ry}=\begin{bmatrix} c & 0 & s \\ 0 & 1 & 0 \\ -s & 0 & c \end{bmatrix} \qquad (11)$$

$$\text{Rz}=\begin{bmatrix} c & -s & 0 \\ s & c & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad (12)$$

The angular orientation can be describe in equation (10),(11) and(12) by roll(α), pitch(β) and yaw(γ) are rotation around X-Y-Z axis. T is translation vector which is each row of translation in X , Y , and Z respectively

$$T = \begin{bmatrix} T1 \\ T2 \\ T3 \end{bmatrix} \qquad (13)$$

The above equation (13) is showing translation vector (T).

The extrinsic parameter are calculate from four camera images, these images are given in Fig. 2 , Fig. 3 ,Fig. 4 and Fig. 5.

Fig 2. The front camera image

Fig 3. The back camera image

Fig 4. The right camera image

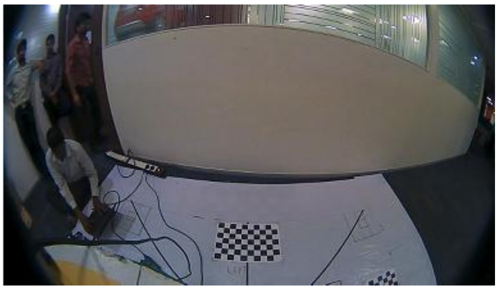

Fig 5. The left camera image

LOOK UP TABLE AND IMAGE BLENDING

A .Look Up Table

The warping and stitching of whole images from the each frame, instead of that we used a look up table method to decrease the computational cost. According to the look up table method, we can get each pixel value of output image from the input of fisheye camera images. When warping of image is done then overlap regions are present in output images. The overlapping region consist of image data from two adjacent image frame. The look up table created for output image frame. In surround view system, output image form on 3D bowl geometry with the help of look up table. The inverse perspective mapping (that is image plane to bowl plane) of each pixel with known image data of input image done with look up table creation.

B. Image Blending

In this paper, we showed result using the standard alpha blending technique. The alpha blending is applied to the overlap region pixels of adjacent images to eliminate residual seam boundaries and making the seam completely invisible. The output pixel are formed by a linear combination of input pixel values weighted with blending weights. The weight value is different for adjacent overlap region images. The blending equation is given below,

$$I_{(x,y)}=\frac{\sum_{i=1}^{n} I^{i}(x,y)w^{i}(x,y)}{\sum_{i=1}^{n} w^{i}(x,y)}(14)$$

where ,equation (14) consist of Ii (x, y) is the image intensity of pixel in coordinate system (x, y) of image I and Wi (x, y) is the weight in coordinate system (x, y) of image i.

The Blending equation applied on camera images, these are given in fig 2 and fig 3. The addition of Fig. 6 and Fig. 7 is given in Fig. 8.

Fig 6. Blending on back and front image

Fig 7. Blending on right and left image

Fig 8. Addition result of Fig 6 and 7.

EXPERIMENTAL RESULTS

The surround view solution is implemented on a TI's TDA2X ADAS SoC with two DSP C66x cores. Our system consists of four fish eye cameras around the vehicle, each having a 180 FOV and 720p resolution. From these four fish eye camera videos, a composite surround view is produced at 30 fps. The composite surround view has a dimension of 450 X 1800. The 450 X 1800 output resolution was chosen to match our display constraints. The front and back fish eye camera image formation done in dsp1 processor and left, rightfish eye camera image formation done on dsp2 processor. The image addition of four camera images done on EVE processor to form 360 degree surround view system.

The TI's TDA2X SoC hardware handling done with the vision SDK (software development kit) software. The vision SDK is multiprocessor software development package for TI's family of ADAS SoCs. In surround view system, vision SDK is consist of bowl geometry, inverse prospective mapping with LUT creation and blending process. The Vision SDK is able take four input from camera and display the output with dimension of 450 X 1800 resolution. The proposed surround view solution produces a composite view as

if car can see from a camera above the car. The final three dimensional surround view around the vehicle is showing in Fig.9,

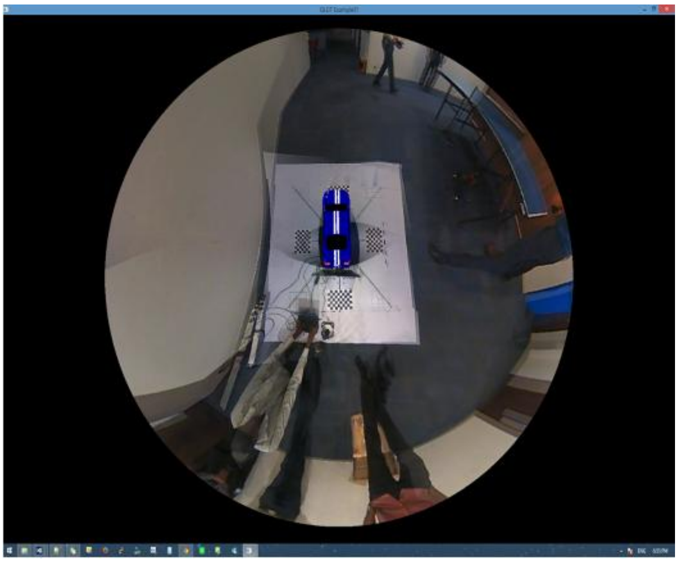

Fig 9. Three Dimensional Surround View Around The Vehicle

CONCLUSION

In this paper, we have developed a real time three dimensional surround view system. It can provide spontaneous and realistic vehicle surrounding scene for drivers. In this system, the four fish eye cameras are attached around the vehicle to capture images of surroundings in all directions. All capture fisheye images are resolved to virtual perspective mapping using the proposed calibration process and these resolved images are stitched into three dimensional bowl geometry by using proposed mapping. Finally, 360 degree surround view image is created by blending all capture images. Our system achieved high quality HD video output at 30 fps. The proposed surround view system can provide the drivers with good conception of surrounding situations and much reduce the risk of car accidents.

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