3D Around View System with Ground Estimation

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Abstract-- **In this paper, a 3D around view system with ground information is proposed to assist vehicle driving. The main objective of this work is to infer the ground information using fisheye cameras to improve 3D model construction, so that drivers can observe more accurately from any angles around vehicles.**

I. INTRODUCTION

A relatively high proportion of car accidents were caused by vehicle blind spots. Therefore, it is beneficial to have a set of auxiliary systems, providing around views for assisting drivers to spot any obstacles around, to enhance driving safety. Most around view systems mount wide-angle fisheye cameras at the four sides of the vehicle in order to get the visual information around the vehicle.

Around view systems for automobiles can be divided into three types: narrow-range bird's-eye view, wide-range bird's-eye view and 3D around view. They all mount multiple wide-angle fisheye cameras around the vehicle. The narrow-area bird's-eye view [2] only allows drivers to observe a range up to about 3 to 5 meters near the vehicle body because distant objects under the bird's-eye view will be stretched and distorted severely. Wide-range bird's-eye view [1] corrects this stretch and 3D around view [3] applies it to 3D model to obtain a better view.

This paper aims at improving 3D around view systems. In the pre-processing stage, we perform contour extraction of calibration patterns to automatically capture corners of patterns so that the process of point selection can be simplified and its accuracy can be increased.

During a car is moving, fisheye cameras keep taking shots of scenes, which are applied to SfM (Structure from Motion) method to track the optical flow, and thus the relative positions of cameras can be determined. After that, Plane-Sweeping method is employed to compute the single-view depth images. The depth images will provide information to detect the ground for correcting our 3D model. In this way, a more faithful 3D around view system can be achieved.

II. PROPOSED METHOD

The flow chart of our proposed method is illustrated in Fig. 1. We will explain the flow as follows.

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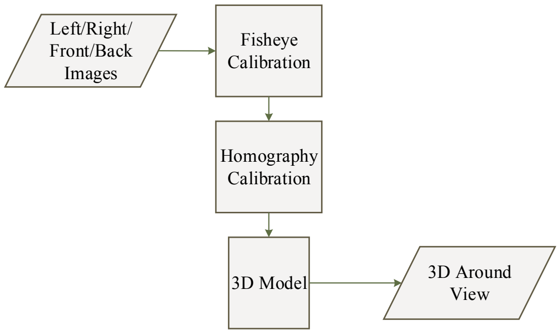


Fig. 1. Flow chart of the proposed method

A. *Fisheye Calibration*:

Our work adopts Urban's [4] fisheye calibration method. In order to estimate the fisheye lens distortion parameters, we take several pictures at the same checkerboard from different angles. We automatically capture corners of each checkboard image to estimate the camera's distortion parameters according to how those corner coordinates are mapped. We can then use these estimated parameters to undistort fisheye images.

B. *Homography Calibration*:

A homography matrix is required to convert from the undistorted images to bird's-eye view images. To obtain the homography matrix of each mounted fisheye camera, we laid out four of our specially designed triangle calibration patterns at each corner of vehicles [3] as shown in Fig. 6, and thus each camera will cover two calibration patterns. We can have six sets of point pairs corresponding to each vertex coordinate x' of two triangles in each camera image. The detected vertex coordinates x' can be converted into the birds-eye view coordinate points x through homography matrix estimation via (1)-(2). The variables x, x' and H are defined in (1) and their conversion relationship is shown in (2).

$$\boldsymbol{x} = \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}, \boldsymbol{x'} = \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix}, \boldsymbol{H} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \quad (1)$$

$$\boldsymbol{x'} = \boldsymbol{Hx} \quad (2)$$

In summary, we first undistort the input fisheye images by the calibration parameters obtained in Section II.A, and then multiply each pixel of undistorted images with homography matrix acquired in Section II.B. Each pixel of undistorted fisheye images will be converted to corresponding coordinates of the bird's-eye view images. Then four bird's-eye view images can be stitched together to constitute the overall bird's-eye view image.

The bird's-eye view image has a serious stretch problem in far distant objects away from vehicles. Therefore, we use a sphere-like model to correct the stretch to a wide-range bird's-eye view system and 3D around view system, and the corresponding 2D to 3D sphere-like mapping is shown in Fig. 2. A look-up table approach between the coordinates of 3D view image and the original fisheye image is implemented to accelerate the mapping.

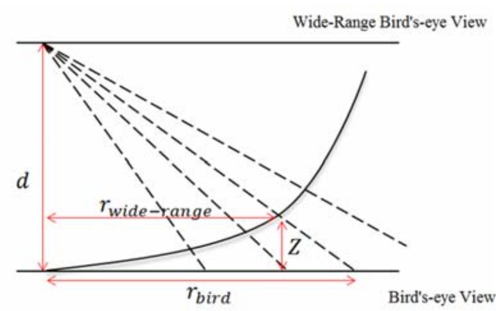


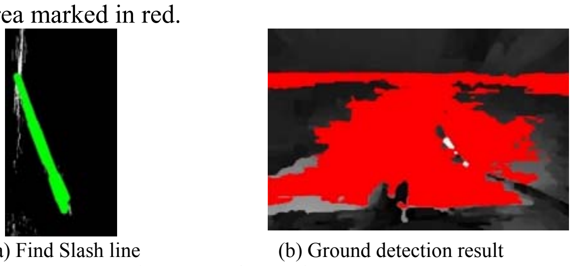
Fig. 2. Wide area bird's-eye view image corresponding relationship

C. Depth and Ground Detection

To enhance the 3D around view system with a better presentation of the ground, Plane-Sweeping method [5] is used for depth estimation, we use calibrated images as input. Fifteen frames are tracked with optical flow and by the depth calculation results with the help of SfM as shown in Fig. 3.

Fig 3. Depth calculation results

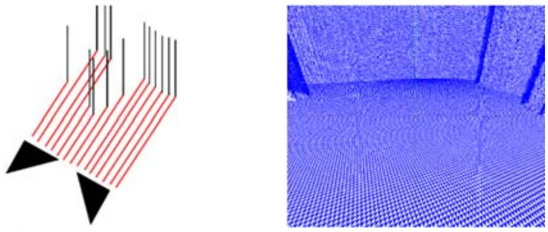
We convert the depth image into a v-disparity image [5], where the horizontal axis is the depth value, the vertical axis is the height of the image. The intensity of v-disparity represents the accumulated number of pixels to the corresponding height and depth. In v-disparity images, the ground will ideally form a line with a slope. Hough line transform can help find out the lines in the v-disparity image, as shown as a green area in Fig 4 (a). We can then use this information to identify the ground area in undistorted fisheye images, as shown in Fig 4 (b) with the ground area marked in red.



(a) Find Slash line (b) Ground detection result

Fig 4. Ground Detection

Once the ground area is identified, we can modify the ground in the 3D model as a completely flat area. That is, the z-axis coordinate in the area equal to 0, and the rest part of the non-ground area will be folded into nearly 90 degrees right angles, as shown in Fig. 5. Finally, we apply the same sphere mapping procedure on this modified 3D model.

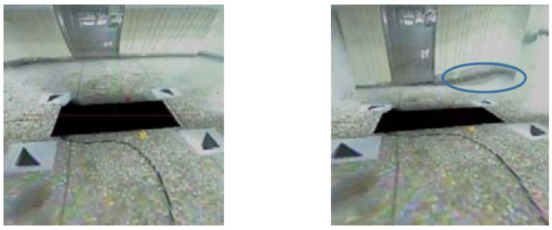


(a) Illustration of 3D model (b) Grid of 3D model

Fig. 5. Illustration and grid of three dimensional model

III. RESULTS

In our experiments, we mount four fisheye cameras around a moving vehicle. Urban's [4] method is used for fisheye calibration. Triangle patterns and automatic contour and corner detection are implemented to estimate homography matrix. Bird's-eye image stretching problem is solved by a look-up table and a 3D model. The ground of 3D model has been added using the plane-sweeping method [5]. Through ground detection, we can improve the surrounding view to be more realistic but sometimes it could has mismatch problems due to inaccurate depth estimation as circled in Fig. 6(b).



(a) Result without ground (b) Result with ground

Fig. 6. 3D around view and corresponding 3D model

IV. CONCLUSION

This work facilitates the pre-processing procedure of around view system, where the homography matrix is automatically calculated. Plane-sweeping is introduced to calculate the depth value and detect the ground area to improve the 3D model and obtain more faithful 3D results. The future work needs to estimate and refine the depth more accurate for better results.

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