Blind-zones Detection using Wide-angle Camera and Distortion Correction of Images for Automotive Applications

Mohammad Obydur Rahman
Automotive Software Engineering
Technische Universität Chemnitz
Chemnitz, Germany
mohammad-obydur.rahman@s2021.tu- chemnitz.de

***Abstract*—Automobile companies have recently become quite concerned about object detection in blind zones. Accidents are often increased by objects in blind zones. Blind-zone object identification can prevent a lot of accidents and financial damage. CAMERA, RADAR, and LiDAR sensors can all be used to find objects in blind spots. The CAMERA sensor may be a preferable option in this situation due to some of its features. The acquired image has some aberrations since wider lenses have a larger field of vision. The removal of distortion from the image is absolutely necessary for both object detection and classification. I will present a CAMERA sensor, particularly a wide-angle camera to detect the object in blind-zones and mathematical formulas that can be used in image processing to remove distortion from the image.**

Keywords— Wide-angle camera, radial distortion, active safety, automotive sensors, an object in blind spots, driver assistance, and wide-angle lens.

I. INTRODUCTION

Due to rising consumer demand in the automobile sector, camera sensors have become crucial for the safety sector. Obstacles in the blind zones are to blame for about 80% of accidents. The European New Car Assessment Program assessment estimates an annual economic loss of about 28.9 million dollars [2]. Camera sensors can save money by lowering the amount of collisions caused by objects in the blind zone. The area outside the car that the driver cannot see clearly when at the controls under current conditions is referred to as the "blind-zone." Blind-spot is another name for "blind-zone" that is also used in this context. Due to the vehicle's size and design, the area, and other factors, blind spots can vary. Blind zones vary depending on the size and shape of the vehicle; for example, a truck has a bigger blind zone than a typical little car. The number of vulnerable road users (VRUs) has significantly increased in recent years. VRUs mostly consist of cyclists and pedestrians, and collisions happen when a vehicle is unable to recognize them while they are in the blind spot.

In this case, the CAMERA is a very significant, frequently used, and affordably cost sensor used in the automotive industry. While RADAR employs radio waves to detect the object, LiDAR uses laser light to do so. Since numerous vehicles are trying to send a signal using radio waves or laser light that will interfere with one signal to another and produce noise in the signal in a traffic-congested area, it is very difficult to determine the actual item and motion. These problems suggest that the CAMERA is a far superior sensor for use in vehicle applications. The camera mimics human vision, which is an important factor in object classification. The most recent advancement in camera technology is a stereo vision which can record 3D images. The size, location, and composition of an object that is present in the blind zone can all be detected by the 3D semantic wide-angle camera. I've split my research into two categories. In the later part of this article, I have represented the form of radial lens distortion for the wide-angle camera and the correction method that inverse the distortion.

II. BLIND-SPOT OF VEHICLE

A blind-spot for a car is essentially the region around the vehicle that, under normal driving conditions, the driver cannot see directly from the typical ocular position by gazing forward or using the vehicle mirrors. The size of the vehicle, the driver's position, and the mirror orientation all affect how large the blind-spot area is.

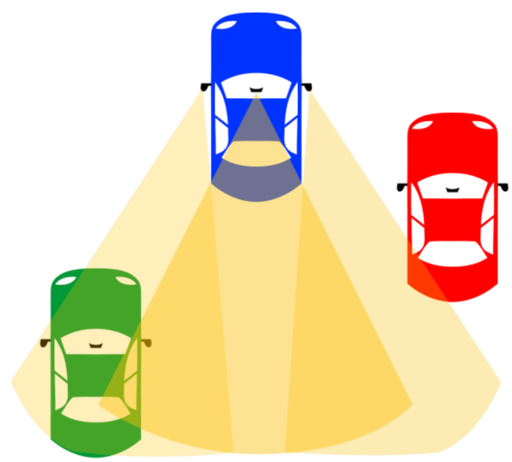

Figure 1: Blind-Spot area of the vehicle [1].

As a result, the calculation of the blind-spot area will be different and calculated by the distance where the object exists, 0.72 m (27.95 inches) skewer traffic necessary to be in front of a man.

A man seated in the driver's seat will be able to see its peak while staring out the back windows. The area was established at 13.4 m (44 feet) for the driver's height and 1.8 m (5 feet 9 inches) for the passenger for a four-wheeler standard vehicle that was registered in 2003. In contrast, the blind-spot area was calculated at 22 m (72.17 feet) for a driver's height of 1.6m (5 feet and 2 inches) [1]. According to the Loughborough Design School (LDS), the blind-spot area for the right-handed truck is 0.6m in front, 1.9 m on the left side of the truck, and 0.02m on the right-hand truck [3].

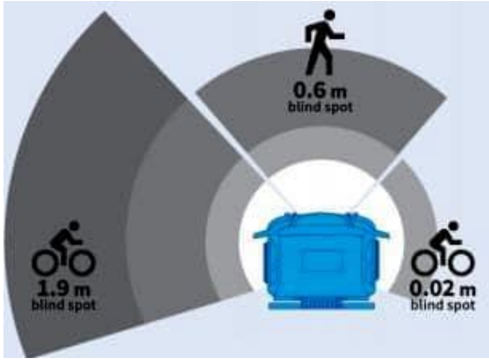

Figure 2: Blind-zones for right-handed Truck [9]

III.STATISTICS OF BLIND-SPOT ACCIDENT

Statistics of Europe

According to the European Union, there are no official statistics for Vulnerable Road User (VRU) death in order to victims are not visible from the driver's ocular position. In spite of it, The European Commission makes its own database for storing accident statistics due to the obstacle detection in blind-zones which was 4,581 in the town area in 2007. Various statistics also support this assumption. The European Commission Communities enumerated that almost 500 death per year due to the object spotted in the blind-zones of large goods vehicles (LGV). According to UK Health and Safety, 630 people lose their lives in a period of twelve months between 2007 and 2008[2].

IV. WIDE ANGLE CAMERA

A. Wide-angle lens

A unique kind of camera with a wide-angle camera sensor can take larger images than other types of cameras. Wider lenses can affect movement and enable larger images from the wide-angle camera. Two common lenses, short-focus, and retro-focus, are used by wide-angle cameras. Short-focus lenses that shorten the focal length have been used with many pairs of spectacles. These glasses have symmetrical front and back diaphragm shapes, and as the focal length is shrunk, so does the distance between the back image plane parts. The short-focus wide-angle lens is unsuitable for this reason even though it has less distortion. This results in a proximity issue. Retro focus, on the other hand, makes use of a single [10].

B. Angle of view

The camera's angle of view demonstrates the angular expansion of the object's desired scene. Another phrase that can be used interchangeably is the field of view. In general, the lens creates a large image circle to cover the camera sensor, and it is possible to add some corner vignettes. When the lens' coverage area falls short of the camera device sensor is possible to see the image circle.

Northey utilized regular carpenter's tools to determine the camera's angle of view in 1916. He describes the angle as a half-angle of view or "the angle that a straight line would take from the extreme outside of the field of view to the center of the lens" and notes that the lens manufacturer has utilized this angle twice. In these tests, keeping the object in the frame necessitates modifying the camera's distance and angle of view. The lens and sensor collaborate in order to identify the camera's angle of view.

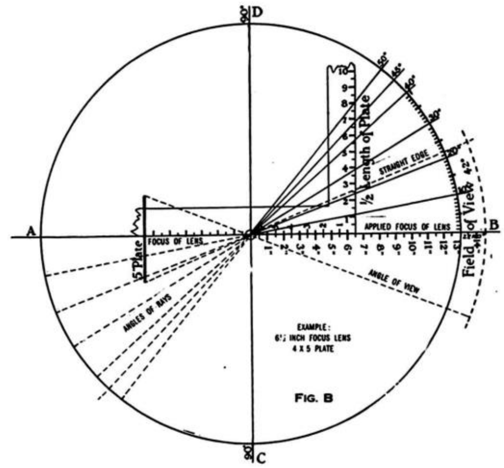

Figure 3: Angle of view using ordinary carpenter's tools [10]

C. Angle of view Calculation

Wide-angle lenses essentially use longer lenses than conventional lenses; as a result, the image that is taken may have considerable distortion. It is possible to quantify the angle of view in three different planes: horizontal, vertical, and diagonal.

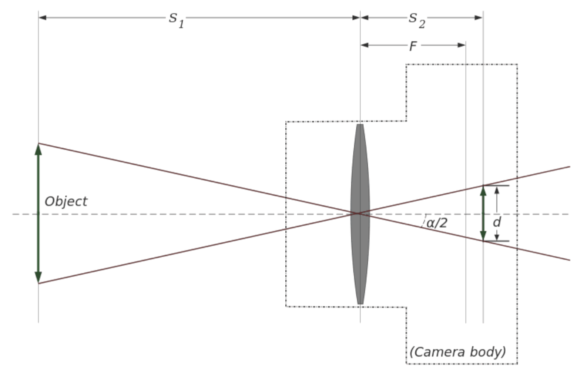

Figure 4: Angle of view using ordinary carpenter's tools [4]

Let's assume that the object's distance for a rectilinear lens is S1, and that d specifies the size of the formed image. The wide-angle lens has a pinhole on the back, and S2 can be used to determine its distance. The angle between the lens' optical axis and the ray joining its optical center can be expressed as α/2, where d/2 is half of the image's dimension from the back. Use of basic trigonometry to define wide-angle view α

$$\tan(\alpha/2) = \frac{d/2}{s_2}$$

$$\Rightarrow \quad \alpha = 2\arctan\frac{d}{2s_2} \qquad (1)$$

The distance of an object s2 and the focal length F have to be identical in order to project an explicit image. The angle view of the image can be presented by

$$\alpha = 2\arctan\frac{d}{2f} \text{ (Where f=F)} \qquad (2)$$

V. *BLIND-ZONE COVERAGE OF WIDE-ANGLE CAMERA*

As was mentioned above, the size of the vehicle for instance, a sports utility vehicle or a huge good vehicle can cause the blind spot to be larger. We'll demonstrate how employing a wider lens camera sensor, drivers can acquire an undistorted image of an object in a blind zone. Figure 5a shows how a regular camera was used to identify the object in the blind spot, but it was unable to capture the entire blind spot. A standard camera has a 45-degree field of view. The coverage area of the FOV 458 lens is 1 m for SUV blind-spot.

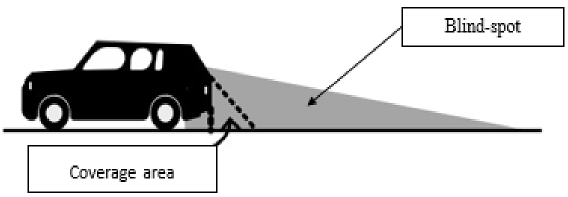

Figure 5a: Coverage of standard lens camera (45°) [1]

The wide-angle camera sensor (Model 1008 FOV lens) is able to capture the entirety of an SUV's blind zone. In this situation, the placement of the camera is equally crucial. The camera with >100 covers the whole blind-spot, as seen in figure 5b.

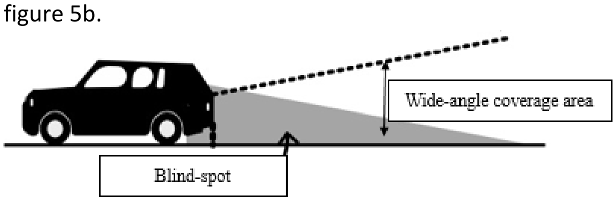

Figure 5b: Coverage of wide-angle lens camera (>100°) [1]

VI. DISTORTION FORMATION AND REMOVAL

For a wide-angle camera sensor for automotive applications, distortion has been a significant problem that needs to be fixed. The camera is a very significant sensor since it can see like the human eye and because it is also possible to extract geometric information from the image. Nevertheless, the FOV standard camera's distortion is hardly noticeable. Some of the effects of wide-angle lens distortion are discussed in the sections that follow. However, the wide-angle camera's radial lens distortion poses serious challenges to visualization as well as the process of object detection and categorization. A larger lens also produces radial distortion, which breaks the obstacle's recti-linearity.

A. Polynomial models for radial distortion

The well-known polynomial model is used to describe the radial distortion of lenses [1] [4] [7]. The embedded perspective claims that polynomials are attractive because they do not require the achievement of the computationally numerical logarithm. On the other hand, a log and tan-based non-polynomial model is required. The radial distorted distance (rd) and the radial undistorted distance (ru), which is directly opposite of rd, have been calculated using the deviation model. The distortion from the desired image has been reversed using this technique. The distortion that results from using a wide-angle lens can occasionally cause issues because there isn't an actual feature to reverse it. Back-mapping is a useful technique in section (VII) that may be used to remove distortion from the image and reform it as an undistorted image. Slam's odd-order representation of the traditional polynomial model for radial distortion is also employed in [5–8].

$$r_d = r_u + \sum_{i=0}^{\infty} k_n r_d^{2n+1}$$

$$r_d = r_u + k_1 r_U^3 + k_2 r_U^5 + \ldots + k_n r_U^{2n+1} + \cdots \quad (3)$$

The distorted radius, rd, is presented in the equation above, together with the undistorted radius, ru, and the coefficients, k. It has been a presumption that (1) is unable to determine the degree of distortion created by the camera's wide-angle lens [7]. Despite this, the fifth-order polynomial of this model may correct the distortion of a picture captured with a normal lens camera.

$$r_d = r_u + k_1 r_0^3 + k_2 r_U^5 \quad (4)$$

Despite the fact that (1) has no precise analytical model for reversion, Mallon and Whelan show a reversion of the fifth order for (2). [8]

$$r_u = r_d - r_d \left(\frac{k_1 r_d^2 + k_2 r_d^4 + k_1^2 r_d^4 + k_2^2 r_d^8 + 2k_1 k_2 r_d^6}{1 + 4k_1 r_d^2 + 6k_2 r_d^4} \right) \quad (5)$$

B. Use of division model to reduce distortion

The division model has been introduced by Fitzgibbon [9]. This model represents the undistorted radial distance for a specific point of the picture as a method of the distorted radial distance of the following points [11].

$$r_u = \frac{r_d}{1 + \sum_{i=0}^{\infty} k_n r_d^{2n}}$$

$$r_u = \frac{r_d}{1 + k_1 r_d^4 + k_2 r_d^4 + k_n r_d^{2n+..}} \quad (6)$$

Although (1) and (4) are in a similar form, it is essential to keep the standard polynomial model, both these equations depict the distortion curve of the image from the wide-angle camera. The division model generates a similar issue with (1), it is not possible to invert the distortion accurately from the image from a wide-angle camera. The division model is appropriate to specific lenses when it is employed with circle fitting [10]

C. Fish-eye transform (FET)

Basu and Licardie established the term "fish-eye transformation," which is another synonym for "wide-angle transformation" In [7]. In this model, the fish-eye image has been seen, and it has been found that the range resolution is very high in the foveal place and somewhat lesser range resolution close to the periphery place. The model was displayed as

$$r_d = s\,\mathrm{In}(1 + \lambda r_u) \quad (12)$$

S has defined the normal scaler, and lambda shows how much distortion is desired for a fish-eye lens camera to capture. The reversion model has therefore been presented as

$$r_U = \frac{e\left(\frac{r_d}{s}\right) - 1}{\lambda} \quad (13)$$

D. FOV model

Devernay and Faugeras have suggested the FOV model in [13] depicts radial distortion and inversion of radial distortion. One way to present the FOV model is as

$$r_d = \left(\frac{1}{\omega}\right)\tan^{-1}\left(2r_u \tan\frac{\omega}{2}\right) \qquad (14)$$

The wide-angle camera's discernible angular field of view is represented by, the perspective model by f, and it's possible that the confusing wide-angle lens optics won't work with this model, which would mean that the FOV of the actual camera technology wouldn't be covered. Additionally, this suggested model might not support the puzzling wide-angle lenses. According to Devernay and Faugeras, (1) must employ the coefficient k1=0 when utilizing (12). Therefore, the distortion reversion model is shown as

$$r_u = \frac{\tan(r_d^{\omega})}{2\tan(\omega/2)} \qquad (15)$$

VII. *RADIAL DISTORTION CORRECTION*

Radial distortion correction is the process of converting a distorted image into an undistorted image. The combination of suitable lenses can eliminate radial distortion from the wide-angle camera's image. According to Bogner [21], the possibility of removing distortion is constrained by the refractive problem. Wide-angle lens cameras require post-processing to change the image to the rectilinear model, and doing so can occasionally be expensive.

A. Calibration

The calibration process can be used to define the wide-angle camera's parameters and remove image distortion. Using the inversion model, it is possible to reverse the distortion in the image by changing each pixel. Despite the fact that it has been thought of as an inversion model. For the majority of the calibration procedure, a calibration model containing geometry in the 3D location is required. To calibrate the wide-angle camera, the calibration features, such as circles, corners, lines, dots, or any other characteristic of the calibration diagram, can be simply extracted. Calibrating the system does not require prior knowledge of the scene. Using a unity of various view geometry, the desired information is collected from the scene in this procedure.

B. Vacant pixels

The stretching effect of the distortion correction process results in many empty pixels in the undistorted image being discarded during mapping. Therefore, the interpolation method suggested in [12] can be employed to resolve this issue. The back-mapping method, on the other hand, can be an additional solution [5]. Each pixel in the deformed image may extend over another pixel during the back-mapping process. The problem with the back-mapping process has been addressed with the use of bilinear interpolation. This method utilized the weighted average of the impacted pixel to enable the back-mapping process to occur with no integer accuracy.

CONCLUSION

In this research, we have discussed the use of a camera sensor in the automotive application and mentioned some mathematical formulas to remove distortion from the image for the wide-angle camera sensor. The wide-angle camera can visualize the object in larger blind- zones. Several models were also reviewed to reverse the distortion and the several effects of individual distortion removal models.

All the distortion is corrected in this resulting image using a back-mapping model. To prove the effectiveness of the methods we described we have to look for a comparison of distorted images in Fig. 6 with the undistorted image in Figure 8. Almost 95% of the distortion has been removed from the distorted image. Now this image looks visually better, the object can be easily identifiable using a wide-angle camera in the blind-zones of the vehicle.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank you Prof. Dr.-Ing. O. Kanoun, Franziska Keil, and the entire Automotive Sensor Systems team for organizing this course and for their collaboration. I've learned a lot about research methodology, such as how to select a research topic with a report, how to create a final presentation, and so on. I have really enjoyed the courses. If I use this archiving knowledge in my next master's thesis, I think I can succeed academically.

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