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Image Based Visibility and Speed Estimation under Fog Condition

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***Abstract*- Fog is considered to be one of the causes of road accidents while driving a vehicle. Therefore, In order to reduce the accidents or at least limiting their impact, vehicles are equipped with Advanced Driving Assistance Systems (ADAS). For this reason, there is a need of system which is capable to detect the presence of fog, estimate the visibility distance and maximum speed that the vehicle should travel. It works for day time fog detection on images.**

Index Terms— Fog Detection, Visibility Distance, Driving Assistance Systems, Speed estimation.

I. INTRODUCTION

The developing and deploying of Advanced Driving Assistance Systems (ADAS) are one of the core technology trends in vehicles that relieve the driver from tedious tasks. In fact, with the help of ADAS, drivers can pay more attention in order to avoid collisions and reduce the risk of accidents during hazardous situations. Some known examples are lane departure warning, automatic cruise control etc.

The National Highway Traffic Safety Administration (NHTSA) states that the weather phenomena are one of the most common causes of automobile crashes. In addition, driver fatigue distracted drivers, aggressive driving, speeding, drunk driving also cause automobile crashes. When the driver engaged with other work 80% of road accidents happen due to 3 seconds of distraction. Although there is an improvement in road infrastructure the numbers of accidents caused by extreme weather conditions is increasing every year. Fog is considered to be dangerous weather condition for driving because as the density of fog increases visibility distance decreases exponentially. One of the survey states that only 2.8% of highway road accidents occurs in good weather conditions but the number doubles in fog. During foggy weather, drivers actually tend to overestimate the visibility distance, which may lead to excessive driving speed. For this reason, we have sought to build a system able to detect the presence of fog in image, measuring the available visibility distance and inform the driver about the maximum vehicle speed on the given road segment.

Fog detection systems based on image were studied in the past years with the aid of detecting the fog and removing there effects from the images. Systems that use onboard camera are less frequently used. Only Pomerleau [1] estimated visibility by measuring the contract attenuation of road features like lane markings ahead of a moving vehicle. This method is based on RALPH system to track and find arbitrary road features. A method for contrast restoring of image gets degraded due to atmospheric condition. They use atmospheric point spread function to characterize the weather conditions. Pavlic [2] developed a method for fog detection based on image descriptors with Gabor Filters at different scales, frequencies and orientations.

Another approach is presented in [3] in which combination of radar and in vehicle was developed. It is based on Koschmieder’s law in which classification of fog density is done according to visibility feature of beyond vehicle. A method for fog detection based on stereo vision is performed in [4]. They perform object detection based on V-disparity method in which depth map of vehicle environment is performed. They introduce a method for estimation of visibility distance in fog condition and this algorithm is based on Koschmieder’s law. Region growing procedure is used to find inflection point in image. In [5] Bush introduced an approach for measuring visibility distance by placing a fixed camera above the roadway. They use stationary images and perform wavelet base contrast measurement, then estimating the distance to the pixel that displays contrast higher than 5%.

Fog detection based on fog density is presented in Bronte [6]. This method goes with the computation of the vanishing point and road lines are taken as reference for computation. When the vanishing point is found then segmentation of road and sky is performed. Fog detection based on contrast restoration is done in Trael [7] which includes planar assumption and no-black pixel constrains and comparison is presented. Bermen[8] developed an approach which was implemented by Caltrans i.e. fog detection an d warning system based on array of sensors that is able to inform the drivers on highway 99 about the visibility and speed. The sensors are placed every half mile on both directions of freeway and required information is displayed on changeable message signs. Since the system is expensive and drivers need to be inform about the weather conditions and speed recommendation to avoid the number of accidents.

This paper is organized as follows. Section II illustrates the overview of system block diagram and section III describes the results and last section present conclusion.

II. BLOCK DIAGRAM OF DETECTION SYSTEM

The overview of the diagram is shown in Fig.1. Color image is taken as input and it is grey converted. Next it is applied to canny edge detector for edge detection. Then we calculate the horizon line and region growing procedure is used to estimate the inflection point in order to detect whether fog is present in image or not. If the fog is present in image, then visibility and speed estimation is performed.

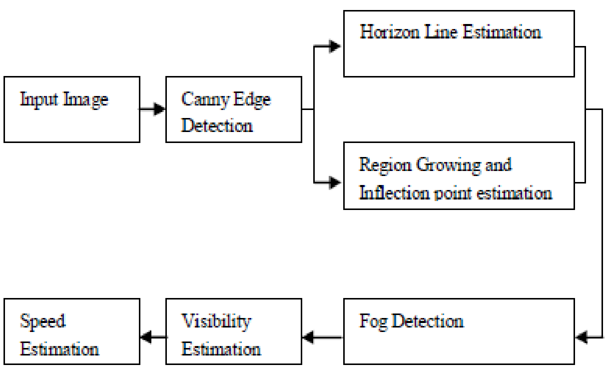


Fig. 1. Block diagram of the system.

A. Canny Edge Detection

Canny edge detection is also known as optimal edge detection. It can be better compare to the other detection methods because of its low error rate and localized edge points. In this first we smoothens the image to eliminate the noise in the image. Then it finds gradient of image in order to highlight the regions with more spatial derivate. Next it tracks along these regions and suppresses any pixel that in non-maximum.

B. Horizon Line Estimation

Better results on horizon line are based on image features. The line in the image will be detected by finding the vanishing point of the painted parallel lane markings. In [12] only two longest parallel lines are taken to find the vanishing point. Then select a set of lines in the lower part of road image followed by Hough accumulator which was built from edge points and then longest m peaks were selected from accumulator. A RANdom SAmple Consensus (RANSAC) approach is applied to find the longest subset of relevant lines that pass through the same image. The sample with the largest consensus set is selected. Then the vanishing is taken as the center of intersection points.

C. Region Growing and Inflection Point Estimation

The region growing procedure is followed as present in Hautiere[4].The aim is to find a region within the image that displays minimal line-to-line gradient variation. Starting from bottom row of the image, whose pixels belong to surface of the road is considered. The pixel of this row is taken as seeded Pixel if and only if intensity is near to the median of the pixels on this row. Then from the bottom pixel i.e. from seed point only the three pixels lying above the current pixel are added to the region if they satisfy the following : the pixel does not belong to the region, it is not edge point, Presents some similarity with seed and pixel located just below. To find the inflection point one can find the similar band like structure in the region. If such region is not found, then there is no fog in the image. If the point lowers the square error between model and measured curve is taken to be the inflection point Vi of the image. Inflection point employs similar temporal scheme as horizon line in order to enhance the robustness.

D. Vision effects of fog using Koschmieder's law

One of the popular models to study fog effect is Koschmieder's model. He studied how luminance is attenuated through atmosphere in 1924. He proposed a relationship between the attenuation of luminance of an object L at distance d and the luminance Lo close to the object.

$$L = L_0 e^{-kd} + L_f(1 - e^{-kd}) \qquad (1)$$

LF stands for atmospheric luminance and k is the extinction coefficient. In this equation luminance of an object will be attenuated by coefficient $e{-kd}$, and gradually deteriorated by luminance of sky at rate of $Lf\ (1 - e{-kd})$. The equation was rewritten by Duntley and the equation was divided by Lf to obtain the Duntley's attenuation law that states that the relationship between an object with contrast *Co* against background and observed the contrast *C* at distance d.

$$C = \left(\frac{L_0 - L_f}{L_f}\right) e^{-kd} = C_o e^{-kd} \qquad (2)$$

This law works only in day light conditions. From the above expression we can derive the meteorological visibility distance i.e. the greatest distance at which an object, having contrast Co=1 of a suitable dimension can be seen in the sky on the horizon. The International Commission on Illumination set a contrast threshold, i.e. 5 %, for the barely visible object.

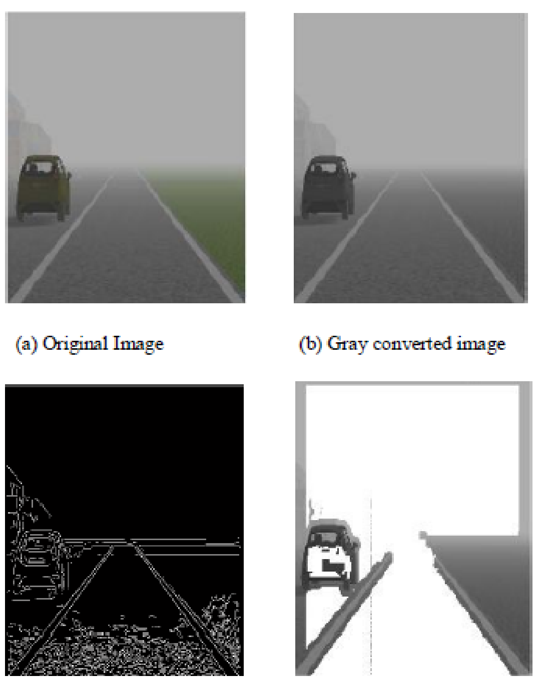
$$d_{vis} = -\frac{1}{k}\log(0.05) \simeq \frac{3}{k} \qquad (3)$$

When dealt with the image, response function of a camera can be applied to equation (1) to map the scene luminance to image intensity. Therefore, intensity perceived in the image is the result of a function (f) applied to equation (1)

$$I = f(L) = Re^{-kd} + A_f(1 - e^{-kd}) \qquad (4)$$

In this case flat world hypothesis is used to estimate the distance to each line in the image. This is valid to the road scenes only, where large part of image is taken by road surface, which is assumed to be planner. So, the distance d of an image line v can be expressed as :

$$d = \begin{cases} \frac{\lambda}{v - v_h} & if\ v > v_h \\ \infty & if\ v \le v_h \end{cases} \qquad (5)$$



(a) Original Image (b) Gray converted image

(c) Canny edge Detection (d) Region growing

Fig. 2. Canny edge detection and Region growing

Where $\lambda=\frac{\propto H}{\cos\theta}$ and Vh represents the horizon line in the image.

Visibility distance is estimated by performing the mathematical properties of the Koschmieder's law and investigating the existence of inflection point in the image. By expressing'd' as in equation (5), obtained the equation (4) as:

$$I = Re^{\frac{-k\lambda}{v - v_h}} + A_f(1 - e^{\frac{-k\lambda}{v - v_h}}) \qquad (6)$$

By taking the derivative of I with respect to v, one obtains

$$\frac{dI}{dv} = \frac{k\lambda}{(v - v_h)^2}\,(R - A_f)\,e^{\frac{-k\lambda}{v - v_h}} \qquad (7)$$

From qualitative analysis one can say that objects tend to get obscured quickly as the density of fog increases. Moreover, the maximum derivative deviates more substantially and decreases significantly from horizon. Then again compute the derivative of equation (7) with respect to V,

$$\frac{d^2I}{dv} = \frac{k\lambda}{(v - v_h)^3}\,(R - A_f)e^{\frac{-k\lambda}{v - v_h}}\,\left[\frac{k\lambda}{v - v_h} - 2\right] \qquad (8)$$

$\frac{d^2I}{dv} = 0$ Equation has two solutions. Take a positive solution of k, so k=0 is not acceptable. Thus second solution is:

$$k = \frac{2(v_i - v_h)}{\lambda} = \frac{2}{d_i} \qquad (9)$$

Vi represents the position of inflection point in image and di represents its distance to the camera. If Vi is more than Vh then fog will be detected in the image, else there is no fog in the image. By equation (3) and (10) we can estimate the visibility distance in the image:

$$d_{vis} = \frac{3\lambda}{2(v_i - v_h)} \qquad (10)$$

E. Detection and estimation

If the horizon line Vh and inflection point Vi are computed, then the presence of fog in the image is detected and estimation the visibility distance from equation (10). Fog categories are estimated based on visibility distance.

F. Speed estimation

Estimation of the vehicle speed travelling on the roadway can be used to find the over speeding vehicle. The accidents that cause during fog conditions are mainly due to excessive driving. Many efforts have been made so that driving assistance system will help to provide safe driving limit to the driver. A method was developed in [9] to determine the sight distance, account the geometry of the road and variable speed limits. Another approach based on

Intelligent Speed Adaptation was implemented in order to avoid the accidents in fog condition i.e. zero risk method is presented in [11].The generic formula to find driving speed is calculated using equation (11).

TABLE1. Fog Categories

Visibility distance		Fog Categories
Max	*Min*	
∞m	1000m	No Fog
1000m	300m	Low Fog
300m	100m	Moderate Fog
100m	50m	Dense Fog
50m	0m	Very Dense Fog

$$V_r = gfR_t + \sqrt{g^2 f^2 R_t^2 + 2gfd_{vis}} \qquad (11)$$

- Rt is the time interval which includes the reaction time of the driver before possible accident may occur.
- g is the gravitational acceleration, 9.8 m/s2..
- f is the friction coefficient,0.35.
- Vr denotes the driving speed.

III. RESULTS

In this section the results of the algorithm are shown. Firstly, the results of canny edge detector is shown, then some results of region growing, horizon line and inflection point is estimated and finally the visibility and speed estimation of the system are described. Fig.2. depicts the images with canny edge detection and region growing. Fig.3. presents the results of horizon line and inflection point with visibility distance and speed estimation. The system was implemented in Matlab and was tested on Windows operating system. We have taken the image with resolution of 591512 pixels and the average processing time is 5 sec and the images with the different resolution are also been checked and verified. Table 1 presents the fog categories based on visibility distance. Theoretical values in the table have been verified with different types of fog based on visibility.

IV. CONCLUSION

This paper represents the system for detecting the fog in the image with the goal of assisting the driver about the fog detection, visibility distance and speed limit in order to avoid the accidents. Based on the computation of the horizon line and inflection point we can detect the fog, visibility distance and speed estimation. Better results are obtained on less crowded vehicles on road segment. An RANSAC approach was used to estimate the horizon line because it proves to be stable and provides better results. In the same way inflection point is estimated using temporal filtering for better results. Thus system developed is used to estimate the maximum speed in fog condition proves to be accurate and able to inform the driver to reduce the driving speed to avoid the collision with other vehicles. In future, the system can be deployed on intelligent mobile devices which can run on Android operating system thus better solution for driving assistance can be obtained.

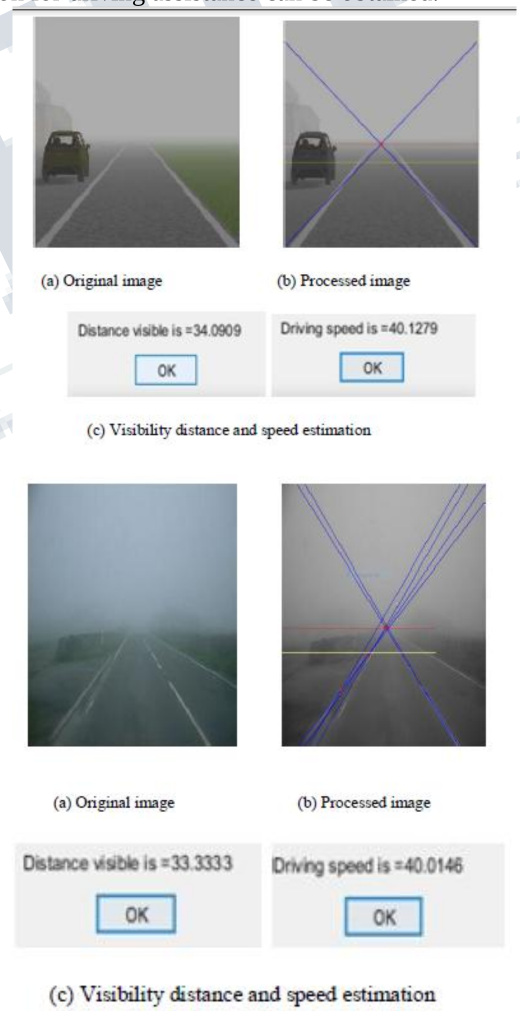


Fig.3. Results obtained on different images. The red lines represents the horizon line, the yellow line represents the

inflection line. The visibility distance and driving speed are displayed below the images.

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