ESTIMATION OF VISIBILITY DISTANCE IN IMAGES UNDER FOGGY WEATHER CONDITION

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Abstract
Fog is considered to be one of the causes for road accidents while driving a vehicle. Limited visibility due to fog poses a significant danger to travelers. Fog fades the colors and reduces the Contrasts in the scene with respect to their distances from the driver. For this reason, there is a fundamental need for Advanced Driving Assistance Systems (ADAS) based on efficient system able to detect the presence of fog, determine the visibility distance and inform the driver about the maximum speed that the vehicle should be traveling. It works for day time fog detection on images.
Index Terms: Fog Detection, Visibility Distance, Driving Assistance Systems.

I. INTRODUCTION

The development of the advanced driver assistance system (ADAS) unobtrusively relieves the driver from a lot of tedious tasks. With the help of ADAS, drivers can avoid accidents or reduce the risk of accidents and drivers can pay more attention and have more time to handle higher-level tasks. Actually, the visibility estimated is also an important indicator to help a driver to drive safely. According to literature, the human eyes estimate 60 % further about the position of vehicles in front under foggy weather than fair weather. In fact, The National Highway Traffic Safety Administration (NHTSA) states that the top six most common causes of automobile crashes are: distracted drivers, speeding, aggressive driving, drunk driving, driver fatigue and weather phenomena. Reduced of visibility due to fog can pose a significant hazard to travelers. Fog is considered to be the most dangerous one because the visibility distance decreases exponentially as fog density increases. When the weather is affected by fog, drivers tend to overestimate the visibility distances and drive with excessive speed [1]. For this reason we developed a system for assisting the driver in foggy situations. Our system is capable of detecting the presence of fog in images, measuring the visibility distance in such situations and informing the driver about the maximum speed that they should travel on the given road segment.

The Advanced Driving Assistance Systems (ADAS) presented in the literature are relying on expensive hardware that is difficult to apply on older vehicles. The proposed system can be ported easily on a modern tablet or Smartphone, making it an inexpensive and accessible by drivers.

Fog detection systems were studied in the past years with the aim of detecting the presence of fog and removing the fog effects from images. Pomerleau [2] estimates visibility in fog conditions by means of contrast attenuation at road markings in front of the vehicle. This approach requires the presence and detection of road markings. This approach is based on the RALPH system, nonetheless requires the presence and detection of road markings in order to proceed. In [3] an approach based on image descriptors and classification is used in order to detect fog conditions. The image descriptors used are Gabor Filters at different frequencies, scales and orientations. The visibility distance estimation in fog conditions is presented in [1]. The algorithm is based on Koschmieder's law and is able to detect the visibility distance in day time traffic scenarios. If fog is present in images they use a region growing procedure for detecting the inflection point in the image. By knowing the position of the inflection point and the horizon line position they are able to compute the visibility distance in the image.

Bush [4] utilized a fixed camera mounted on the road or overhead structure to detect fog. This method exploits some advantages like foreground detection, which can be used to improve accuracy of object contour detection. The general idea of Bush's method is to detect the furthest pixel, whose contrast is greater than 5 % in the contour of any object in the captured image. Later, by estimating the distance of the furthest visible pixel to host-vehicle, visible range is deduced. It was a very popular idea at first. However, since it is a static application, it may involve lot infrastructure problems. Thus, many researchers later shifted their focus to the on-board sensors application.

In [5] a method for fog detection based on the computation of the vanishing point is presented. The road lines are taken as reference lines in order to compute the vanishing point. After the vanishing point is found a segmentation of the road and sky is performed. This method is able to classify fog based on its density. The number of accidents that happen during fog conditions result in a high number of casualties, there is a growing concern in providing assistance to the drivers. One such approach was implemented by the California Department of Transportation [6]. They have developed a fog detection and warning system based on an array of sensors able to detect fog. These sensors are deployed every half mile on both direction of a freeway. In addition this system is able to provide drivers with information about the fog density and visibility distance. The information is displayed on Changeable Message Signs. Although it is a very expensive system the fact that the drivers are informed about the weather conditions and visibility reduced drastically the number of accidents on this highway. Our intention is to develop a more cost effective approach to the problem of fog detection and to inform the driver about the visibility distance on the given road segment.

This paper is organized as follows. Section II illustrates overview of system architecture and last two sections present results and conclusions.

II. BLOCK DIAGRAM OF DETECTION SYSTEM

The overview of our framework is presented in Figure 1.In this method color image is taken as input and it is grey converted. Next it is applied to canny edge detector for edge detection. Then we estimate the horizon line and the inflection point in order to assess whether fog is present in the image. If fog is present in the image, then visibility estimation is performed.

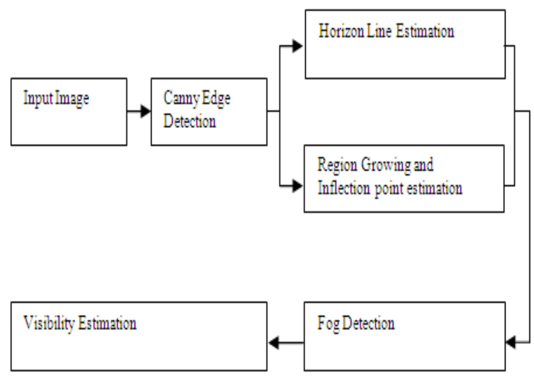


Figure 1. Block diagram of the system

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 image is smoothen to eliminate the noise. Then it finds gradient of image in order to highlight the regions with more spatial derivates. Next it tracks along these regions and suppresses any pixel that in non maximum.

B. Horizon Line Estimation

The horizon line in the image will be detected by finding the vanishing point of the painted quasi- linear and parallel road features such as lane markings. In [6] only the two longest lines are considered for finding the vanishing point. A more statistical approach that uses more lines and was previously used to find the vanishing point of the parallel lines from pedestrian crossings was preferred. Select a set of relevant lines in the half lower part of the image (road area). The Hough accumulator was built from the edge points in the interest area. A RANdom SAmple Consensus (RANSAC) approach is applied to find the largest subset of relevant lines that pass through the same image point. The sample having the largest consensus set is selected. The intersection points of each distinct pair of lines from the largest consensus set are computed. Finally, the vanishing point is computed as the center mass of the intersection points.

C. Region Growing and Inflection Point Estimation

The region growing process follows the guidelines presented in [1]. The objective is to find a region within the image that displays minimal row to row gradient variation. Starting from a seed point only the three pixels above the current pixel are added to the region. If they satisfy the a seed point, only the three pixels above the current pixel are added to the region if they satisfy the following constraints: the pixel does not belong to the region, it is not an edge point and presents a similarity with the seed and the pixel located below. The inflection point can be found by estimating similar band like structure in the region. If such band is not found in a region, then there is no fog in the image. If the point minimizes the square error between model and measured curve is taken to be the inflection point V_i of the image. In order to increase the robustness of the inflection point computation, a temporal scheme similar to the one for horizon line detection is employed.

D. Vision effects of fog using Koschmieder's law

One of the most important and popular models used to study fog effect is Koschmieder's model. Koschmieder [8] studied and revealed his model of how luminance attenuated through atmosphere in 1924. In this equation, he successfully linked the degradation of luminance with the distance of an object.

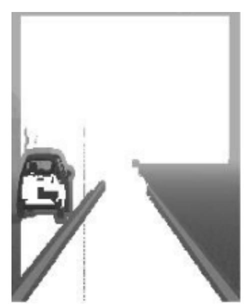
$$L = L_0 e^{-kd} + L_\infty (1 - e^{-kd}) \quad (1)$$

L_∞ is the atmospheric luminance and k is the extinction coefficient. This equation states that the luminance of an object seen through fog is attenuated with an exponential scattered by fog between the object and the observer is expressed by L_∞ ($(1 - e^{-kd})$By re-writing this equation and dividing by L_∞ one can obtain Duntley's attenuation law [1] that states that an object having the contrast Co with the background is perceived at distance d with contrast C.

$$C = \left(\frac{L_0 - L_f}{L_f}\right) e^{-kd} = C_0 e^{-kd} \quad (2)$$

This law can be applied only in day light uniform illumination conditions. From this expression the meteorological visibility distance is derived (d_{vis}) "the greatest distance at which a black object, having contrast (Co=1), of a suitable dimension can be seen in the sky on the horizon". In order for an object to be barely visible, the

(a) Original Image (b) Gray converted image



(c) Canny edge Detection (d) Region growing

Figure 2: Canny edge detection and Region growing.

International Commission on Illumination has adopted a threshold for the contrast, i.e. 5%. It results that

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

When dealing with images, the response function of a camera can be applied to the Koschmieder's equation in order to model the mapping from scene luminance to image intensity. Thus, the intensity perceived in the image is the result of a function (f) applied to equation (1):

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

A_∞ is the sky intensity and R is the intrinsic pixel intensity.

In the case of a single camera, the flat world hypothesis can be used to estimate the distance to each line in the image. This hypothesis is used in the case of road scene images, since a large part of an image is formed by the road surface, which can be assumed to be planar. So, the distance d of an image line v, can be expressed by the following equation:

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

Where $\lambda=\frac{\alpha H}{\cos\theta}$ and V_h represents the horizon line in the image. The value of d from equation (6) will be used in order to assess the visibility distance in fog conditions.

E. Distance Estimation

Visibility distance is estimated by performing the

mathematical properties of the Koschmieder's law presented in the previous section. For estimating the extinction coefficient k we must investigate the existence of an inflection point in the image that will provide the basis for our solution. By expressing d as in equation (5) and by performing a change of variable, equation (4) becomes:

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

By taking the derivative of I with respect to v, then following is obtained:

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

From qualitative analysis one can say that objects tend to get obscured more quickly when fog density increases. Moreover, the maximum derivative decreases significantly and deviates more substantially from the horizon line. So the inflection point in the image can be found where the derivative has a maximum value. By computing again the derivative of I with respect to v, we get the following equation:

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

Equation $\frac{d^2I}{dv^2} = 0$ has two possible solutions. For positive solution of k, k=0 is not acceptable. Thus the solution obtained is:

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

V_i represents the position of the inflection point in the image and d_i represents its distance to the camera. If the position of inflection point and horizon line is computed then extinction coefficient is performed using Koschmieder's law. If V_i is greater than V_h fog will be detected in the image, otherwise we conclude that there is no fog in the scene. From equations (3) and (9) visibility distance in the image is estimated.

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

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F. Detection and estimation

Once the horizon line V_h and inflection point V_i are computed, we can detect the presence of fog in the image and can estimate the visibility distance d_{vis} from equation (10).

Table 1. 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

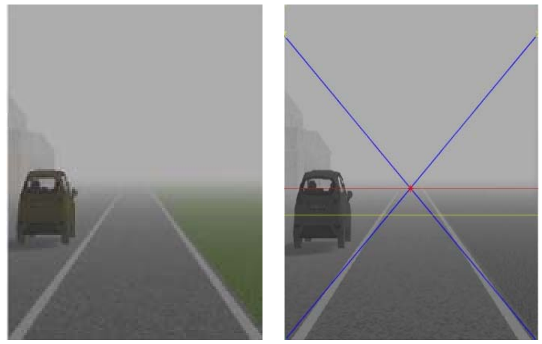
III. RESULTS

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 estimation of the system are described. Figure 2 depicts the images with canny edge detection and region growing. Figure 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. The image is taken with the resolution of 591×512 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. CONCLUSIONS

This paper represents the system for detecting the fog in the image with the goal of assisting the driver about the visibility distance in order to avoid the accidents. Based on the computation of the horizon line and inflection point we can detect the fog, visibility distance. We can obtain the better results on less crowded vehicles on road segment.

One of the main contributions is RANSAC approach is 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 visibility distance 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.



(a) Original image (b) Processed image

c) Visibility distance

(a) Original image (b) Processed image

(c) Visibility distance

Figure 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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