IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 7, July 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

Conventional Approach to Night Time Visibility Analysis and Estimation Method in the Presence of Dense Fog and Halo Characteristics

Dr. Mohammed Abdul Waheed[1], Soumyashree[2]

[1]Assosciate Professor, [2]P.G.Student
[1 & 2]Department of Computer Science & Engineering,
VTU Regional Centre for PG Studies, Kalaburagi, Karnataka, India.

***Abstract*— Fog leads to reduced visibility, it limits the contrast and it disturbs our perception. It limits our ability to view other objects on the road side in foggy weather. It just creates an illusion leading to misjudging the distance between objects causing road accidents. Fog distorts our perception of speed, it makes difficult to distinguish between moving objects and stationary objects, hence leading to loss of life. Hence we need a method to detect the fog and tackle with it. So we propose a method to detect the fog using two detection methods one using the backscattered veil using correlation index (ZNCC) to match the images with reference images and another detection method is by using halos around the external light sources. By using these two methods we detect the presence or absence of fog. Once we detect the fog in the image, by applying dark channel prior, we are going remove fog from the images and we can easily restore the fog free images. And this proposed system works nearer to accuracy and gives the best result.**

***Keywords*— Advanced driver assistance systems (ADASs), advanced lighting systems, Onboard camera, fog characterization, fog detection, night fog, visibility.**

I. INTRODUCTION

The concept of fog is a Natural Environmental phenomenon, though the concept of fog is older and it exists from many years, it has gained more attention these days, because of its effect on Life of humans (drivers). Fog is a type of cloud, which touches the ground, fog may be dense (thick) or light (thin) based on dense and light fog the visibility of humans differ, fog can be so dense, that it makes the passing vehicles and huge monuments almost impossible to see. Fog is found when water vapour, or water in the form of gas, gets condensed. During the process of condensation, water molecules combine with each other to focus the liquid droplets. Hence during night time when light is intended on the water droplet, it scatters the light in all the direction, and some of the light is even scattered towards the drivers eyes, hence making the visibility weaker, this process is called back scattering of light or backscattered veil. There are many different types of fog, namely Radiation fog, Advection fog, Valley fog and freezing fog. Radiation fog is the fog which occurs during night time, this is formed when heat is observed by the Earth's surface during day and it is radiated at the evening, forming fog at night time, hence our work deals with the Radiation fog which causes night time visibility problem. Advection fog is found when the moist and warm air passes over the cooler surface of the earth. During winter season, the fog which is formed in mountain valleys, is the valley fog. The top of the mountain which are caused by the cloud, falls the freezing fog. The best example for freezing fog is Antarctica. The below figures shows the example of the above fog types.

(a) (b) (c)

Fig. 1 (a) Radiation Fog (b) Valley Fog (c) Advection Fog

So, this was all about the fog and its effects which is the main concept dealing in our work. So we shall see the further proceedings of how we can tackle the fog to reduce the accident death rates, during night time. During day light we can easily recognize the presence of fog with our base eyes, but at night it becomes highly difficult to identify the fog, which may lead to disastrous accidents. So it is necessary to find out the presence of fog. So in order to tackle the problem caused by fog, first we need to identify the presence of fog, through onboard camera. Second, based on the images captured by onboard camera, and based on the intensities, the ADA will indicate you the range of fog, i.e., the type of the fog you are facing, whether a dense fog, normal fog or Light fog (negligible fog). So based on this indication the drives will adjust his speed of the vehicle. But identifying the fog, and indicating the type of fog is not enough to reduce the problem caused by fog. In our work we approach to defog the images already captured by the onboard camera. If we defog the images, thus it could help to reduce the risk factor in true manner, so that the driver can view the road more clearly and this could actually help to prevent the accident and reduce the death rate. To view the altered visibility caused by fog, we have two approaches. First based on Backscattered veil, we will detect the fog. Second, if Backscattered veil is not appropriate we switch to detect the fog by observing halos formed around the public street lights. These two approaches will run alternately to detect the presence of fog.

II. Related Work

In earlier research papers, the researchers have gone through the problems of fog and they have tried to overcome the problems by applying different, rules, methodologies and algorithms and tools. When we consider fog as a risk, many factors corresponds to it, such as speed, visibility, meteorological distance, friction etc.

So in the earlier proposed paper [1], they have approached to control the speed to increase the safety on the foggy roads, this idea of controlling speed have been inculcated in an Adaptive Intelligent speed Adaptation System (ISA), with two novelties, one is the reference speed, another is the modulation of the reference speed in the adverse weather condition. Coming to the concept of colour and contrast affected by the presence of fog, presented in [2], have proposed algorithms to handle the speed, adjusting the colour and gray scale images captured by camera based driver assistance system, they have involved the algorithms which improves the contrast of the image and providing little view of the road. The same concept of contrast and visibility can also be seen in [3], but they have concentrated more an defogging the capture image by Advanced drives assistance by proposing a Markov Random field model' to get the more refused, restored and clear image so that it leads to reducing the road accidents to great measures. The evaluation of this demonstration has shown very good results compared with any other algorithm proposed, hence in this way they have approached to improve the visibility of view of the road, with other vehicles and any other obstacles. The earlier approaches works to overcome the problem of fog involving the factors like speed, colour, contrast, here visibility is focused more in [4] [6], to deal with the problem of reduced visibility caused by fog, they have approached the use of two algorithms, using ADA's, one algorithm detects the veil and another detects the halo's, around public light sources, in addition to these in [6], the fog is characterized based on the range like, dense fog, fog, light fog, hence using these algorithm they have found to deal will the problem of visibility caused by fog.

In [5] [6], to identify the presence of fog, final fog, standard night visibility index is used, when compared to all other earlier approaches, where there was no idea of index. Hence the usage of index has helped to some extent to easily identify the presence or absence of fog. Concept related to fog detection in [7], is totally different from the earlier approaches, because they have involved different factors with respect to earlier factors like speed colour, contract, backward scattering, in [7], they have proposed a way to estimate fog depending on Forward scattering and the perspective based on adaptive lighting by the vehicle for safety, using the semi-Monte Carlo ray tracing software.

Till now we observed that the earlier research carried out using ADA's but [8] has utilized the CCD (charge-coupled device) to visualize the effects of fog. In [8], the researchers have just gone step by step to analyze the effect of fog, so initially they have studied the nature of fog and used microphysical models to describe about droplet size distribution, next they have observed the interaction of fog droplets with light and used optical descriptors to well describe the scattering phenomena, finally they have analyzed the effect of fog leased on the contrast induced by the scattering phenomenon in the image received by the system, hence in this way they have analyzed the meteorological visibility by the use of CCD cameras. The main focus of [10] is based on detecting day time fog and analyzing the visibility distance with respect to road and sky. This approach includes the use of Koschmedri's Law for calculating the meteorological visibility distance, the main advantage is that this model encodes with the small no of restrictions, I mean there are not much restrictions for proper working of this model, leading to appropriate results.We have seen the use of ADA's and CCD's cameras bring used in previous research, but [11], makes the use of an on board, b&w camera again this system is used to calculate the visibility distance estimation using camera projection equations, one more purpose of this system is to warn the ADA's about the possible wrong working, and it is observed to work well and have produced good measured results.

III. Implementation

System implementation is one of the important task of any project, it is the way of making things to work in reality. Our implementation is based on the use of three modules. So let's see the modules which have been involved in our work.

Modules:

Whenever there is formation of fog, the visibility alters, so based on the altered visibility balance, a system is made to use three modules, among these three, two modules detect the presence of fog and the left one module defogs the captured images by the onboard camera so let's name of the modules.

1. Detection of Backscattered veil.
2. Detection of Halos around light source.
3. Defogging the images captured by onboard camera using dark channel prior in Night time visibility.

Modules Description:

Let's discuss the modules in detail, which we have mentioned in above title. So let's start with the description of first module that is detection of Backscattered veil.

i. Detection of Backscattered veil:

This is the first module, which is based on backscattered light through headlamp of the vehicle. This Backscattered light or veil (partial visibility) is formed when the light from the headlamp induced on fog containing minute water droplet's, which scatters the light is all direction, hence some of the light is even scattered backwards to the driver creating a veil in front of him leading to reduced or partial visibility.

The below figure shows how it effects the visibility.

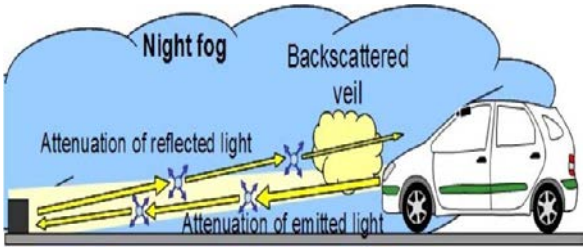


Fig. 2 The effect of Backscattered veil due to the formation of night fog

The Backscattered veil is formed when there are no other external light sources like public street lights or tail lights or headlights of any other vehicle on the road. Basically in simple Backscattered light is formed when the vehicle is alone on the road or highway.

Whenever the condition of Backscattered veil occurs, the onboard camera captures the scenes, and the captured image is matched with the reference images which are already ¸stored, using correlation index. The reference images may be real images, i.e., the images which are captured in foggy weather or it might be synthetic image, the synthetic image is just like simulation, i.e., we manually create fog chamber and making it appear near to real foggy weather and capturing the images and storing these as reference images. In our work we use a synthetic reference image, created using Monte-Carlo ray tracing software. The below given figure shows the actual image grabbed by the camera and the synthetic image captured using the Monte-Carlo Ray tracing Software.

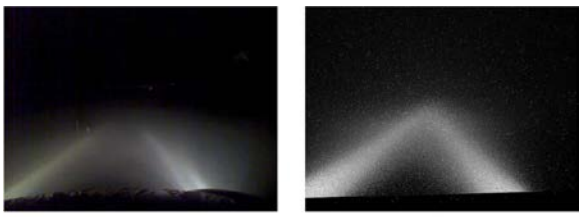


Fig. 3 (a) The actual captured image in Fog and (b) The synthetic image captured using Monte-Carlo ray tracing Software.

When we create such synthetic reference images, we need to take care of the things like, focal length of camera, its resolution, the headlamp intensity and many more, which should be as same as that of real setup on a system, and it should click the images which resembles, nearer to real time images as captured by real camera from the moving vehicle.

Whenever we use synthetic reference images, the captured synthetic reference image are not exact what we desire to be as real time image, we need to make some conversions, i.e., we need to convert it into 8-bit image and normalization is expected to be done between the range 0 to 255. In addition to these, the gamma (γ) function is also adjusted. When we store the reference images they are not similar, we store reference images based on the meteorological distances, i.e., some images may be of meteorological distances, i.e., some images may be of meteorological distance 50 m, 100 m, 150m, 200 m and so on. We can store as many reference images based on the database. Based on fog the intensity of light varies with respect to time for Backscattered veil, hence no of successive images are captured by on-board camera and mean pixel value is calculated. Other way of calculating this value is by application of Rank filter, median. Using Rank filter, the unnecessary objects in the images like lane marks and other objects are removed from the image, and the left out is only the Backscattered light, hence calculation becomes easy which is as shown in the below figure.

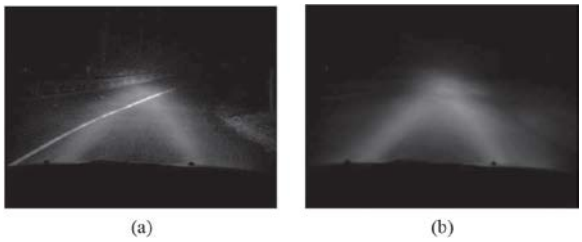


Fig. 4 (a) The actual image grabbed while driving. (b)The image obtained after applying the Rank Filter (median).

After capturing the input images, these images are compared with the reference images, using correlation index. One thing we need to note down that, we exactly don't know the setting of the onboard camera, hence the images captured by on-board camera and synthetic reference image has different dynamics and different pixel value. So we need to apply the appropriate correlation index. There are many types of correlation techniques some of them are SAD (Sum of Absolute Differences), ZSAD (Zero mean Sum of Absolute Differences), SSD (Sum of Squared Differences), ZNSSD (Zero Mean Normalized Sum of Square Differences), ZNCC (Zero mean Normalized Cross Correlation). Among these many correlation index, we use ZNCC because it is more reliable when compared to other correlation index.

The ZNCC provides the appropriate measures, but due to the dark part in the images, which is around the backscattered veil, makes the ZNCC calculation weak, and fails to discriminate properly. So to overcome this problem, we use Otsu's Binarization method, and this method is applied only in the region where veil is formed, hence making the calculation measurable. The Threshold value is calculated, then the correlation score is matched with Threshold value, based on this value the output is provided with presence or absence of fog.

This was about the first method to detect the presence or absence of fog. Now let's move on to the second method of fog detection.

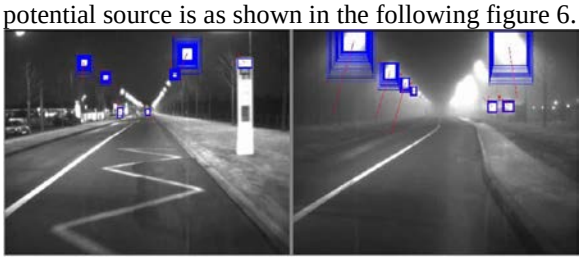
ii. Detecting the fog by the Formation of halos around street lights:

Whenever there are other light sources, such as public street lights, taillights or headlights of other vehicles on the road, the Backscattered veil disappear, I won't say it completely disappears it exists but it is invisible to driver's eyes because of other light sources, this is because of the formation of halos around the light sources. The intensity of the halos depends upon the density of fog.

So let's see how fog is actually detected using this method of formation of halos. Some of the steps involved in this are as follows.

a) Finding Light Source:

This is the initial and basic step in calculating or detecting the fog, i.e., we need to identify the light source. During the dry weather, we can identify the street lights separately but during foggy weather, and because of the presence of moisture in the fog, the halos are formed around the street lights and we can't separate light emitted by each street light, they all seems to be connected, hence these are called connected components. And these street lights are known as "Potential Source" required for calculation. Because light source plays important role, the other things like lane marking and other objects are discarded from the scene. Based on the connected components and potential source, a tree is built to find out the threshold value.The detection of potential source is as shown in the following figure 6.



(a) (b)

Fig. 6 (a) The street lights without fog seems to be different component.(b)The detection of potential source in the presence of fog seems to be as connected component.

b) Segmentation of Halo:

After detecting the potential source and connected component, the formed halos are segmented to find out the threshold value. The halo is segmented iteratively unless we get the same threshold values, i.e., we calculate the threshold value after each segmentation step, if the calculated values remains same then we stop iteration and we get the tree value.

c) Selection of Halo:

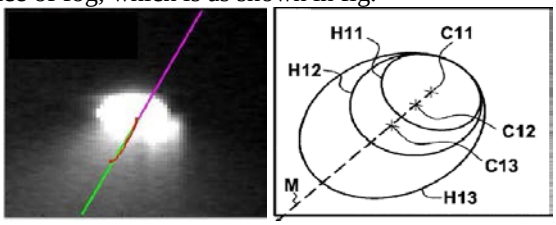
Among various potential sources, one potential source with halo is selected and direction of the halo is computed based on the Center of Gravity (COG) of segmented halo, based on this computation the direction of the halo is found.

d) Extracting profile of halo intensity:

In the previous step, by using COG, we have computed the direction of the light in the presence of halo, now using the direction, the intensity of light is calculated formed by the halo. So finding the direction of light is essential in order to calculate the intensity of light.

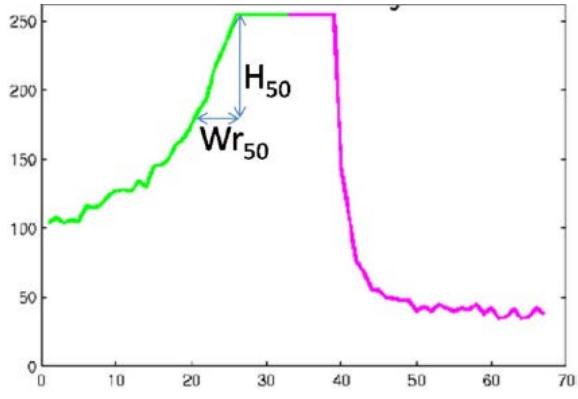
e) Based on intensity profile, characterize the halo:

In the dry weather, the intensity of light is very high, but in the presence of fog, the intensity of light decreases along with the direction of light, and there is rapid reduction in the intensity of light in the dense fog. There are some quantities which describe it better whether there is presence or absence of fog, which is as shown in fig.



(a) (b)

Fig.7 (a) The calculation of intensity of light along its direction.(b)This is the geometrical representation of how intensity of light is calculated and how the threshold is determined where H represents Halo and C represents Center of Gravity(COG).



(c)

Fig.8 The graphical representation of the above intensity calculation which further finds br_{50} Value

The quantities which characterize intensity are $Br_{50} = H_{50}/Wr_{50}$, these are Breadth, height and width of the light intensity, in the presence of fog, these all quantities gets reduced to half of the value.

f) Based on Br_{50}, detecting the fog:

From each segmented halo, calculate the Br_{50} value, then find the average mean value of the Br_{50}, after calculation, store the value as Br_{50}. Suppose that, the computed threshold value was 9. If the calculated $\bar{Br}_{50}$ is less than threshold value 9, then it

indicates that fog is present, if the $\bar{B}r_{50}$ is greater than 9, then there is no fog present in the weather.

iii.Combination of the both detection methods:

Since both the approaches try to detect the presence of fog, so it's better idea to combine these both approaches and execute the program. Though both of these approaches use different calculations and methods, it is better to combine these to get nearer to accuracy value. The pictorial representation is as shown.

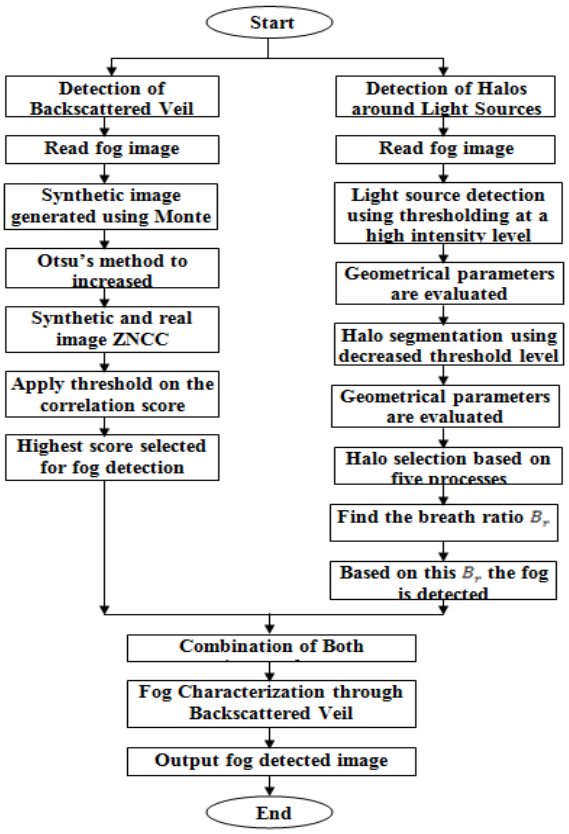


Fig 5.6: Flow diagram of proposed system

When we run these methods, first the algorithm used to detect the halo formation is executed, if no external sources are found, then the control is directly shifted to the algorithm used to detect the presence of fog using Backscattered veil.

iv. Characterization of Fog using Backscattered veil:

We have characterized the fog using halo formation around light source using the standard quantity Br_{50}, but using Br_{50} in the Backscattered veil to characterize fog is not possible, hence we characterize the fog in Backscattered veil, using correlation score (Sc). In reality, we actually don't know the exact distance between the camera and the object in the presence of fog, hence it becomes difficult to measure value using Br_{50}, so we use correlation score, it has found to be reliable and provides the accurate meteorological distance.

Hence, the calculate a standard equation which is a correlation score Sc, using meteorological visibility v_{met}, which is as shown

$$Sc = e^{av_{met}^2} + bv_{met} + C$$

Where a, b and c are parameters, and using the above equation, we can measure visibility V_{met} as

$$\tilde{v}_{met} = \frac{-b}{2a}$$

Hence this method is 0so useful in characterizing the fog through Backscattered veil.

v. Defogging / Fog Removal using dark channel prior in night time visibility:

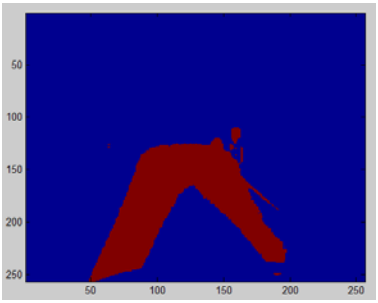
Fog leads to the main degradation of outdoor images, weakening both colours and contrasts. Here we propose a simple but effective "dark channel prior" to remove fog. The dark channel prior is a kind of statistics of outdoor fog-free images. It is based on the key observation most local patches in outdoor fog-free images contain some pixels whose intensity is very low in at least one colour channel. Using this prior with the fog imaging model, we can directly estimate the thickness or density of fog and we will be able to restore the high quality fog free image. The obtained result on a various foggy images describes the power of dark channel prior as proposed in this work.

IV. RESULTS

After implementing the proposed system on Matlab platform, the results obtained are as follows:

Identifying the backscattered veil when no other external light sources are present on the road side.

This image is got after applying correlation and Rank filter.



The identification of the halo formed around the light sources.

The Image shows the removal of the fog from the foggy image captured by onboard camera.

V. Conclusions

We proposed a system which is the combination of different modules to detect the presence of fog, through the images captured by on-board camera and then defogging these images and providing these cleared vision images to Driver so that we reduce the accident rates to higher extent. Now a days, due to the Global warming and increased earth's temperature adverse weather conditions are formed or occurred oftenly, when such adverse weather conditions like, Rain, fog, snow fall occurs, it becomes really very difficult and very dangerous to travel during Night time. Human life is most precious and there should not be loss of life for such weather conditions. So to reduce the death rates caused by Night time Road accidents, we come up with such system, which alerts the Night drivers and extending their safety margin. The main focus of this system is to make the Night time travelling safer, even in such adverse weather conditions. The results provided by this system is found to be nearer to accurate, and it works as desired by the user.

Hence our system works starting with detecting the presence or absence of fog based on two algorithms, one to detect the fog using Backscattered veil, another using the formation of the halo around the external light source, and based on the threshold values, correlation scores and on the value of Br_{50}. The fog is detected and classified and after processing the result is given to the user. And this device or system will find wide popularity and acceptance in coming days.

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