

Enhancing Visibility Range in Foggy Weather by Contrast Stretched CLAHE (CS- CLAHE)

Anmol Jain, Nirvikar

Abstract: Road accidents are becoming a very common problem due to unfavorable weather conditions like rain, fog, and pollution etc. The reason behind such accident is due to poor visibility outside, on the roads and hence driving becomes a problematic issue. Poor visibility becomes due to atmospheric trend originated such as fog, mist originated by small particles in the air such as dust, smoke or moisture, which reduces the visibility of the outdoor scenes. In this paper we are suggesting a Contrast Stretched CLAHE (CS-CLAHE) which will enhance the visibility of outside environment to take necessary precautions for prevention and avoiding the accidents. In the situation of real time streaming, there is a sequence of multiple frames per second, which are to be processed for enhancing the streaming. Therefore, this paper will discuss as a first step: how to enhance a single image and at second stage, processing of multiple images of streaming in parallel processing environment. For fast processing FPGA model is suggested.

Keywords: fog, CLAHE, video stream, FPGA

I. INTRODUCTION

Road accidents are most common problem due to outdoor scene degraded by weather conditions like fog, mist and rain. Specifically foggy weather conditions degrade the color and contrast of the image. Bad weather conditions in which constituents droplets are very small (1-10 μ m) are called steady, like fog and mist, whereas dynamic weather contains droplets of size .1 -100mm, like rain and snow[9]. Steady weather conditions are very crucial challenges. To understand the effects of steady weather conditions we should understand the optical model of image formation in such situation.

A. Optical Model of Scattered Image formation in steady weather: Weather degraded images are modeled in computer vision by the following equation:

Degraded image= Direct Attenuation + Air light
 $f(x) = \xi f(x) e^{-\alpha d(x)} + \xi (1 - e^{-\alpha d(x)})$ where ξ is atmospheric light, which is globally constant, f is reflectance of an object in the image α is atmospheric attenuation and d is distance between the object and object server. When scattering coefficient α is large the then thick foggy scene transmission $(1 - e^{-\alpha d(x)})$ is small, consequently air light is dominated by atmospheric light. And this effect decreases the contrast and increases the brightness of the image [9].

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Histogram equalization is the basic preprocessing technique for improving the contrast of an image so it becomes visible. But when we increase the contrast, brightness changes so Gupta Bhupendra suggested that contrast and brightness can be maintained by Gamma Correction and weighted probability distribution of luminance pixels [8]. Anisa proposed use of white balancing which eliminates the color cast of atmospheric color and applied CLAHE, which formed less spurious edges and restore the color as in natural scene. On the basis of comparative result average PSNR of RMSHE, RSIHE, CLAHE, AGCWD, AGCPF on more than 25 images, it can be identified that CLAHE is having the maximum PSNR [10]. It is known that higher the PSNR value, higher the image quality and hence better visibility of the image objects. Different video camera has different color models like RGB, HSI, HSV, and YCbCr. It is difficult to process video frames in RGB color model so Yoon suggested and implemented HSV color space model. He modeled S channel for atmospheric light and V channel for image intensity [10]. In this paper Yoon enhanced the visibility of foggy video frames by a combination of atmospheric light and transmission map with consideration of temporal correlation of consecutive frames.

II. LITERATURE REVIEW

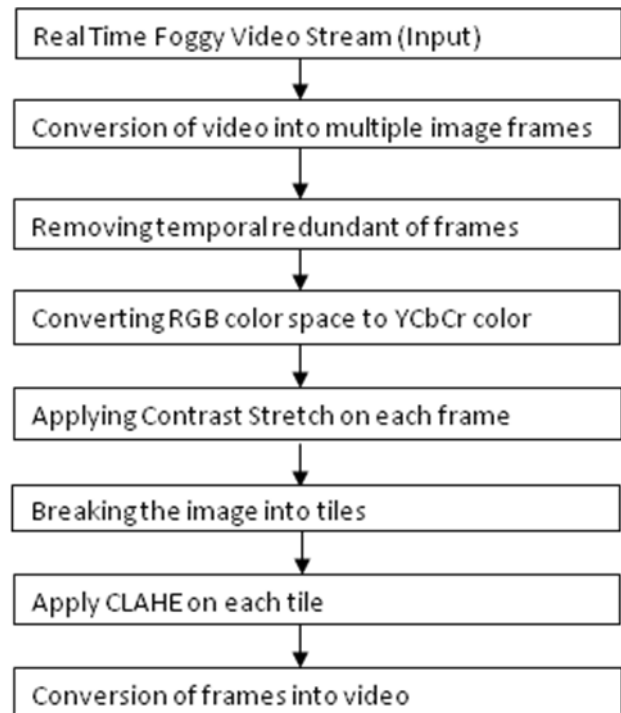
Basically histogram equalization is an image enhancement technique which changes the brightness and contrast of the image. Adapted enhancement restricted contrast using adjusted histogram to minimize the troubles of over enhancement, saturation artifacts and change in brightness with usual histogram equalization [1]. But the limitation of the algorithm is that it does work for improving the contrast of grey images but did not suggest a solution for color images. Gupta et.al proposed that contrast and brightness can be improved by using the Gamma Correction and weighted probability distribution of luminance pixels. This method enhances contrast of all type of color images without much affecting its visual and color information[2]. The use of white balancing which eliminates the color cast of atmospheric color. This approach generates a saliency map followed by morphological opening and applied contrast limited adaptive histogram equalization (CLAHE) technique. This approach results with less false edges and restore the color in a normal scene [3].

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In digital image processing, when we process the color images for enhancement then we also take of color model such as RGB, HSI and YCbCr which are appropriate for different applications. H., Paik, Joonki presented a defogging color correction in the HSV color space for video processing as RGB model is not suitable for video frames processing [4]. In HSV color space atmospheric light can be modeled with S channel and intensity of image can be modeled with the V channel. This paper enhanced the visibility of foggy video frames by a combination of atmospheric light and transmission map with consideration of temporal correlation of consecutive frames. Ansia has compared the result of different histogram equalization RMSHE, RSIHE, CLAHE, AGCWD, AGCPF on the on the basis of parameter Absolute Mean Brightness Error (AMBE) and Peak Signal to Noise Error (PSNR) [4]. Apurva proposed a method for images with too much sky background, in which transmission map of the image is changed by DCP (dark prior channel) [5] and followed by Fast Fourier Transform. After FFT processing, scene radiance is corrected by which an improved image is obtained which has lost the effects of bad weather conditions and improve enhance the contrast of the processed image. This method is suitable for surveillance purpose [6]. Alain proposed an enhancement method on the basis of color and geometry of the scene. This method implemented a joint color-spatial directional clustering followed by a statistical planner region merging method. It reduced the computational time as compare to other methods [7]. HE, DCP, BPBHE, enhanced the degraded image due to fog, mist, haze. These different climatic issues have different brightness in the image, which creates problem to identify the target. Therefore, to handle various brightness conditions due to different climatic issues, Kaur suggested adjusting the brightness component of the image by introducing the parameter of Gamma Correction. Gamma correction will be able to adjust the different value of gamma for different climatic conditions [8].

III. ARCHITECTURAL FRAMEWORK FOR FOGGY VIDEO ENHANCEMENT

Real time foggy video stream may be captured in two ways: In first situation the camera is in static state and area under observation is dynamic like video surveillance at gates. In second situation video camera is also moving like when we are driving car. Here we are considering the surveillance cameras and video capture is under foggy weather. The objective of the model is to reproduce the camera video in enhanced form.



IV. COMPARATIVE STUDY OF EQUALIZATION TECHNIQUES

Enhancement technique	Advantage	Disadvantage	Limitation
HE	Easy to implement	Loss of natural brightness	Not suitable of color images
RMSHE	Better background brightness enhancement	Loss of contrast.	Not suitable for medical images, Unable to preserve the brightness of color images. Not suitable of color images
RSIHE	Maintain the brightness of the image	Repeated segmentation of histogram	Stopping Criteria of segmentation
CLAHE	Suitable for natural image analysis. Preserve brightness	Loss of information	Finding the value of clip limit
BBHE	Easy way to implement	Poor brightness preserve	Not suitable for medical images. Not suitable of color images
DSIHE	Preserve better brightness than the BBHE, and CLAHE	Improper enhancement quality	Not suitable for medical images
MMBEBHE	Better result for color image as compare to BBHE	Not suitable for industrial application	Color conversion model
RSWHE	Better result than the BBHE	Selection the value of gamma	Finding the weight value for pixels
AGCWD	Suitable for medical image analysis because of changing the value of gamma	Selection the value of gamma	Finding the correct value of gamma for different image application. Mean brightness is not preserved
BPDHE	Brightness of input image is almost equal to intensity of output image	Time consuming as processing is done two times	Not suitable for industry applications.

Following is the overview of the processed algorithm for this function:

Conversion of video into frames: By using MATLAB functions, the algorithm will convert the video into multiple frames.

Removing Temporal Redundancy: A video consists of a time oriented sequence of frames –images[9]. A video is viewed a series of image in stacked in the temporal dimension. The frame rate of the video is almost 15 frames

/sec, so the thought of consecutive frames are usually comparable, unless certain objects in the scene move quite fast. Here we are focused to the case where cameras are static, so we can say that video has temporal redundancy. The frame work of model takes the video stream of foggy weather from outside, as camera is static and area under observation is changing. As camera is static so most of the time video will have temporal redundancy,

therefore it is not required to process each frame of video. It will be feasible to take 2 video frames per second and process them using contrast limited adaptive histogram equalization.

Conversion of color model RGB2 YCbCr: In digital video processing YCbCr color model is most appropriate so if the imaging device is of RGB or HSV color model, we translate the image frames of RGB into YCbCr color model[9]. The relation between RGB and YCbCr color space is defined by the following matrix equation.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} .299 & .587 & .114 \\ -.17 & -.33 & .5 \\ .5 & -.41 & -.09 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 0 \\ 0.5 \\ 0.5 \end{bmatrix}$$

In this color model, Y component represents Luminance (Luma) and Cb and Cr components represent Chromacity (Chroma).

V. PROPOSED METHOD CS-CLAHE

In our proposed method, we are applying contrast stretching (CS) on the image. The purpose of contrast stretching is to increase the dynamic range of the grey levels which has been lost due to foggy weather [11]. The stretching process is applied in accordance with P_{in} and P_{out} are the input and output pixels, respectively. i_{min} , i_{max} , o_{min} , and o_{max} are the minimum and maximum intensity level values for the input and output images, respectively.

$$P_{out} = (P_{in} - i_{min}) \left(\frac{o_{max} - o_{min}}{i_{max} - i_{min}} \right) + o_{min}$$

After getting contrast stretched image which covers the entire range of intensity levels of degraded image due to fog, we apply CLAHE operation. CLAHE technique is applied on equal size of partitions, called *tiles*, rather than the entire image. It computes the contrast change function for each tile individually. Each tile's contrast is enhanced, so that the histogram of the output region more or less matches the histogram specified by the uniform distribution value. The neighboring tiles are then combined using bilinear interpolation to remove falsely induced boundaries.

CLAHE algorithm is performed on each individual partition as a sequence of following steps:

- 1: Divide the contrast stretched image into a number of non-overlapping related partitions of equal block size of the 20x20.
- 2: Analyze the intensity histogram of each relative partition.
- 3: Put the clip limits for clipping the histograms, (for example $c=0.002$). The clip limit is a threshold parameter for efficiently altering the contrast of the image. We set a minimal optimal value of clip limit in such a way that it does not increase the contrast level of local images.
- 4: Modify histogram of each tile by the selecting an appropriate transformation functions.

5: Height of histogram of any tile should not cross the selected clip limit.

Conversion of frames into video: Selected frames processed through Contrast stretched and CLAHE operation will be converted into frames using bilinear interpolation and then converted into video. The conversion of frames into video is converted through MATLAB function.

VI. EXPERIMENT AND RESULTS

The main reason for degraded images is poor illumination which affects the brightness of the images. The main causes for illumination may be effect of back light, cloudy season, location of light source, intensity of sunshine etc... Here we expose the comparative study of CS-CLAHE with other existing algorithm like HE, MMBEHE, RSHE, RMSHE, BPDHE. The main drawback of this algorithm is to maintain the mean brightness in the processed image, but our approach CS-CLAHE stretches the contrast level of poor illumination up to full range of intensity level of image.

In this technique, the image is partitioned into size of 20*20 tiles, and the contrast level of each tile is stretched and then CLAHE technique is applied to the each tile. Hence it spans the entire range of contrast.

The objective of contrast stretch is to minimize the image brightness by converting the gray level distribution of input image into a complete range of gray levels, and the purpose of CLAHE is to convert the histogram of an input image nearer to uniform histogram.

CS-CLAHE method produces better results but losses the color-information of the sky in the background in case of foggy weather. On the other hand the CS-CLAHE method is able to improve the contrast of given image without much changing its color-information and natural appearance. The results are measured and compared on AMBE (Absolute Mean Brightness Error) and PSNR (Peak Signal to Noise Ratio).

AMBE is used to calculate difference in mean brightness between two images [2]. Mathematical expression to calculate AMBE between two images is given as:

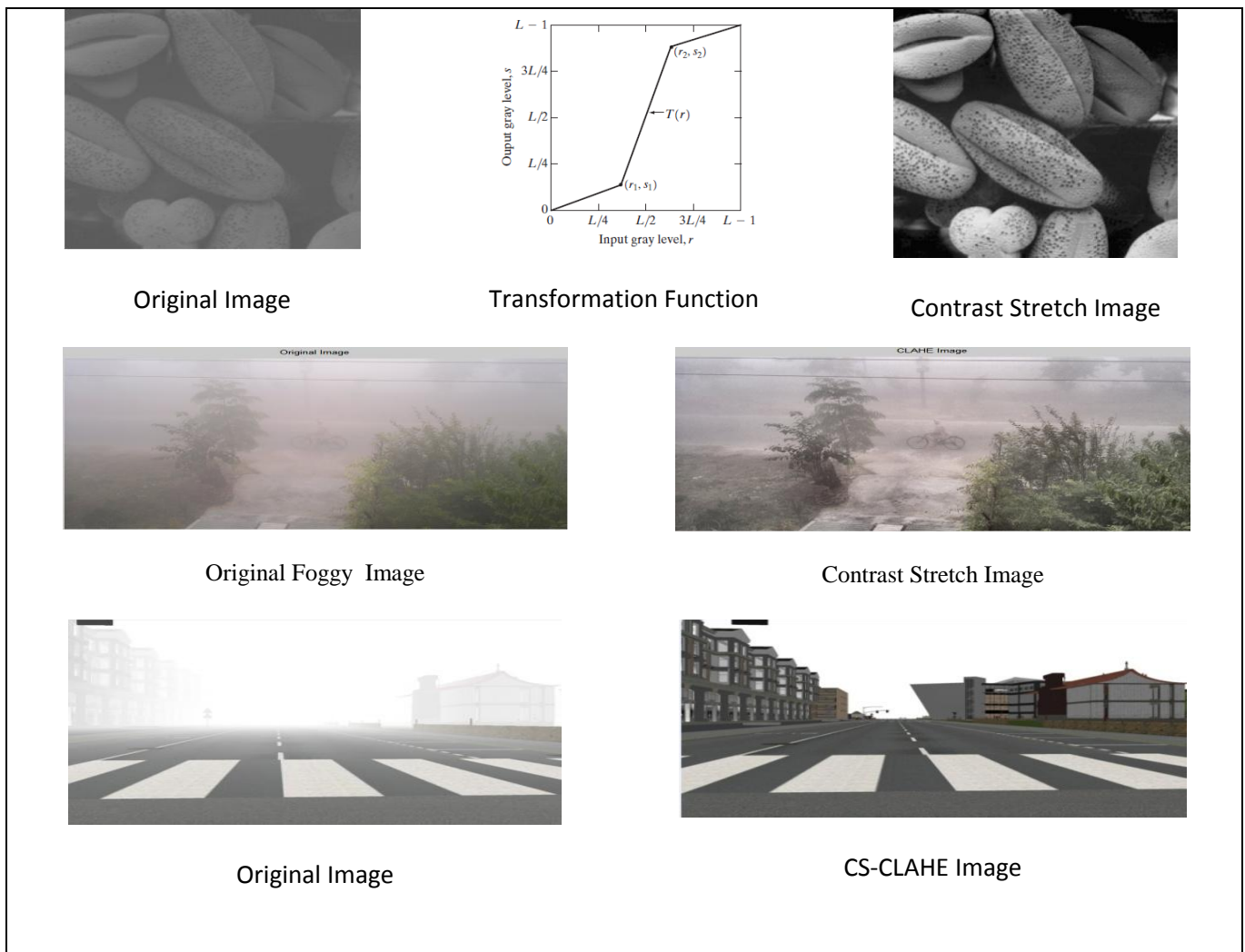
$$AMBE = |\mu_1 - \mu_2|$$

where μ_1 and μ_2 are mean brightness of input and processed image respectively. Based on results of Table 1, we observe that the projected method has least values in all 12 images as compare to other methods. Further if we look at last row of Table 1, which indicate the best average AMBE value among other values.

Table 1 Comparison of AMBE of different histogram equalization techniques

Image	HE	RMSHE	RSIHE	BPDHE	MMBEBHE	CLAHE	CS CLAHE
img 1	34.98	8.75	4.38	3.65	7.36	33.376	0.024
img 2	35.338	1.784	8.324	2.56	25.36	29.17	0.011
img 3	58.271	7.797	7.088	15.23	14.26	22.077	0.036
img 4	40.03	5.952	1.411	24.23	14.38	32.549	10.32
img 5	63.714	4.504	14.053	21.03	15.36	40.72	21.36
img 6	2.382	5.522	3.01	27.32	119.35	33.263	21.3
img 7	42.255	7.026	1.705	2.14	14.34	36.037	0.024
img 8	119.1	24.613	50.735	25.36	52.36	48.232	0.029
img 9	3.278	10.831	18.494	17.36	21.26	27.806	12.36
img 10	50.577	8.043	3.217	18.73	28.36	34.718	11.25
img 11	37.307	3.07	4.218	24.2	24.39	31.385	0.005
img 12	13.849	10.385	16.1	10.35	21.32	30.044	0.018
Averag	41.76	8.19	11.06	16.01	29.84	33.28	6.39

e



Comparison of image quality is carried out by computing MSE and PSNR.

Mean square error: The mean square error (MSE) for the processed image should be minimal for good results [8]. The formula for getting the mean square error is given as MSE:

$$MSE = \frac{\sum_{j=1}^m \sum_{i=1}^n I[i,j]^2 - O[i,j]^2}{m \cdot n}$$

I(i, j) and O(i, j) are input image and processed image of m × n dimensions.

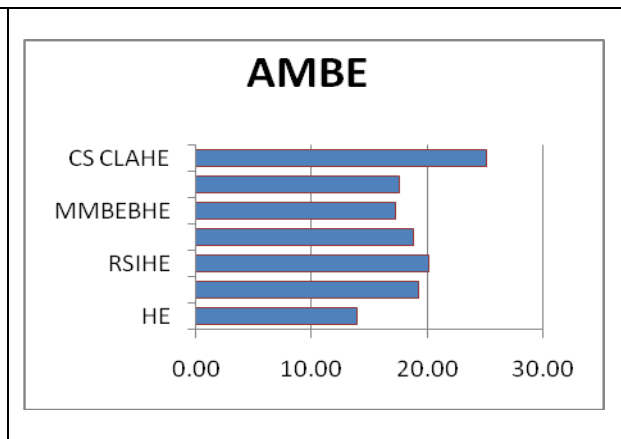
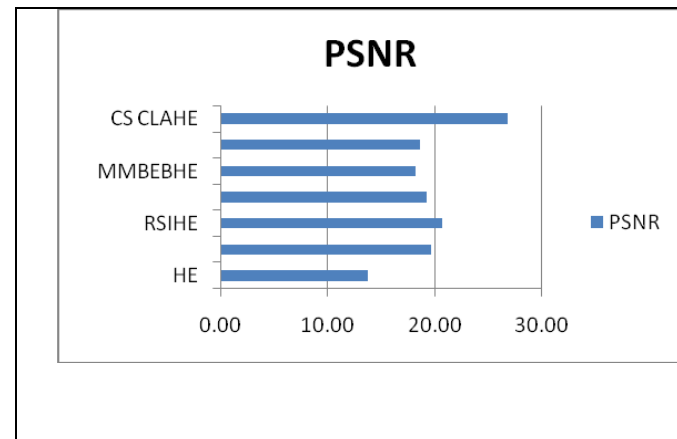
Peak signal to noise ratio Peak signal noise ratio (PSNR) is defined as [12] :

$$PSNR = 10 \log_{10} \frac{255^2}{MSE}$$

It is known that higher the PSNR value, higher is the image quality.

[Comparison of PSNR of various equalization techniques]

Image	HE	RMSHE	RSIHE	BPDHE	MMBEBH E	CLAH E	CS CLAHE
img 1	11.43	21.25	25.25	19.46	14.32	26.32	26.32
img 2	13.65	17.67	19.53	21.4	25.32	14.35	19
img 3	10.31	15.8	18.88	22.01	14.26	15.96	17.25
img 4	13.49	21.68	25.36	19.86	22.35	24.26	31.73
img 5	9.98	23.19	17.66	18.69	21.39	21.65	23.65
img 6	23.04	21.68	22.63	17.47	19.25	16.59	56.23
img 7	13.66	20.33	22.73	17.81	18.25	18.32	23.21
img 8	5.78	13.95	9.9	18.53	11.34	14.36	18.23
img 9	18.03	18.28	18.19	21.73	17.23	18.25	29.31
img 10	12.71	22.28	26.94	19.27	16.28	19.26	34.35
img 11	13.94	20.31	23.156	18.17	16.35	14.23	25.31
img 12	19.39	20.15	19.18	16.99	23.28	20.32	18.26
Averag	13.78	19.71	20.78	19.28	18.30	18.66	26.90



VII. CONCLUSION

: In this paper we discussed two parameters PSNR and AMBE. PSNR states that the greater the PSNR, better is image quality. Here, we have compared our approach CS-CLAHE with previous existing technologies like linear un-sharp masking approach, CLAHE, RMSHE etc... and CS-CLAHE has higher the PSNR from other approaches. CS-CLAHE algorithm produces better quality image because contrast stretch expands the complete range of intensity levels while CLAHE maintains the equal brightness in the entire image. At a final point of discussion, CS-CLAHE works well in the presence of noise, as it was able to augment the contrast gain of that images without amplifying the noise. Implementation of CS-CLAHE on a video (sequence of frames) is very complex and hence moves towards to time complex problem. Therefore, further is t is recommended that CS-CLAHE will be implemented using hardware with FPGA for fast and efficient processing for real time video applications

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