# Single Image Haze Removal using Contextual Regularization

**C. Shobana Nageswari, M.N.Vimal Kumar, K.Ilamathi, R. Mamtha**

***Abstract*: Haze is a condition where our visibility gets affected due to particles, smoke, dust and moisture which are suspended in air. Haze reduces the visibility. A contextual regularization de-hazing algorithm is proposed which uses a single frame image for enhancing the foggy image using multilevel transmission mapping. Quantitative parameters such as MSE and PSNR are considered to assess the superiority of the proposed method. The proposed method is fast and free from noise when compared with other existing methods.**

***Keywords* : Haze Removal, Contextual Regularization, MSE, PSNR**

## I. INTRODUCTION

The Haze, fog or mists are the atmospheric condition in which dust, smoke and other particles reduces the visibility. Haze generally occurs when the smoke and dust particles gather in the dry air. A series of reactions such as scattering, absorption and refraction occurs between the particles present in the atmosphere and have an effect on the visibility. The major source for the formation of haze includes volcanic ashes, traffic, industry and wildfires. Generally the visibility of an image is reduced by two different methods. Either the objects cannot be seen due to obstacles or due to the scattering of the light. The presence of haze become a foremost problem in computer vision applications such as remote sensing, navigation, video surveillance and target identification, etc. Haze formation also has a major impact on the airplane runway. Many road accidents have occurred due to the haze formation which relatively reduces the visibility.

The scene depth information of the corrupted image is a significant factor for haze removal. Various methods extract depth information from multiple images and also extra information. Furthermore, binary scattering model is used to extract scene information from color images under dissimilar weather conditions.

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Polarization properties of different scattered light are applied to re-establish the depth information through the polarized light in different directions. Although these methods produce remarkable results, they require to use multiple images of the same scene or necessitate user interactions and other extra information. These necessities make it difficult to meet the real time requirements.

The proposed method of an enhanced refinement technique uses air light estimation for multi level transmission maps using different block size followed by bilateral filtering for better noise removal and edge enhancement. A Contextual Regularization de-hazing algorithm is proposed to energetically renovate the transmission map and restore the visibility. This algorithm allows us to include filter banks into image de-hazing. The proposed method is speedy when compared to existing methods.

## II. LITERATURE SURVEY

In contrast maximization method the contrast of the image is diminished by the haze and it can be enhanced by removing the haze. The contrast maximization method is proposed by which the contrast of the image can be improved under constraint. This method removes the haze by calculating the atmospheric light. But this method has many disadvantages. The de-hazed image contains halo effects and the saturation value is greater due to the fact that this method does not enhance the brightness physically. [1]. The Contrast Limited Adaptive Histogram Equalization (CLAHE) technique improves the underwater images. This method translates the image from RGB to HSV. Furthermore, the histogram is cropped and distributed to gray level. The processed image from HSV color space is transformed back to RGB. The CLAHE method improves the contrast and visual quality of the image and also reduces the noise and artifacts. [2].

An adaptive technique for de-hazing method uses single image for enhancement. The depth of the scene and every pixel in the image are degraded by the haze. Chao-Tsung Chu and Ming-Sui Lee assumed that the transmission in each region must be same as the degradation level affected in that region. The affected image is divided and transmission is calculated. Then soft matting is implemented and haze free image is recovered. [3]. Dark Channel Prior (DCP) method removes haze from single image. Dark channel prior method is proceeded by estimating the atmospheric light and transmission. Dark channel is generally carried by considering the lowest intensity value. The intensity of the dark channel of an image is considered as a rough approximation of thickness of haze. Pre processing and post processing are performed to attain high-quality results.

The halo effect formation is the major disadvantage of this method [4].Raanan fatal proposed a method for estimating optical transmission from a single image in hazy scenes. The scattered light is calculated to increase the contrast and visibility by removing the haze. Independent compound analysis method is used. Moreover, two additive components are separated and this method does not work for dense haze. [5].

An improved method based on Dark prior channel and Histogram implements soft matting with the help of bilateral filter. The small scale texture of the image is smoothened by the bilateral filter. This method removes the haze in dense haze regions also. Drawback of this method is occurrence of gray scale degeneration. [6]. A de-hazing model of remote sensing images that uses weighted guided filter for removing the gradient reversal artifacts. This method produces gradient reversal artifacts, and halo artifacts. [7]. Xia Lan, Liangpei Zhang developed a method by considering noise and sensor blur. The developed method is a three stage algorithm. Initially, the image is pre-processed and the noise is removed. Then the atmospheric light and transmission are calculated. Finally, a regularized method is applied to remove the haze more effectively. [8]

## III. EXISITING METHODS

The haze removal method formed into two categories such as single and multiple image haze removal technique. Single image haze removal restores the image by assumption based on the information present in the single images. In multiple image haze removal method, multiple images of the same picture will be taken and the known parameters will be considered. Polarization based method is based on multiple image haze removal. Multiple images are captured using multiple polarization filters. These filters are attached to the camera. Images can be acquired by rotating the filters. This method cannot be applied to densely hazed pictures.[9], Depth map based method is implemented with multiple images for haze removal. 3D geometrical model and texture of the scene is considered in this approach. This model aligns the image and provides scene depth.

Dark channel prior method uses atmospheric light estimation and transmission. Dark channel is generally carried by considering the lowest intensity value. The intensity value is reduced due to colorful objects, dark items or shadows. The intensity value of the dark channel is considered as a rough estimate of thickness of haze. The lower intensity of a foggy image appears darker than the region with dense fog. Air light makes a foggy image to appear brighter than its original image. Therefore the intensity of a dark channel in a foggy image have superior intensity than the region with fog. Pre processing and post processing steps are performed to improve the quality of foggy images. Ineffective halo artifact elimination is the shortcoming of this method [6]. CLAHE technique enhances the contrast of the hazy image without considering the predicted weather information for processing of hazy image. The captured image is changed from RGB to HSV values. Histogram equalization technique is implemented on a contextual region. [10].

## IV. CONTEXTUAL REGULARIZATION

An enhanced image refinement technique has been proposed based on air light calculation. This method uses multi level transmission maps using different block sizes followed by cross bilateral filtering for better noise removal and edge enhancement. A Contextual Regularization de-hazing algorithm is proposed to repair the transmission map dynamically and achieves effective visibility restoration.

The image which is affected by environmental factors like smog and fog is acquired as input. The air light function is the multiplication of two factors such as atmospheric luminance and inverse of depth map. Air light estimation is performed to realize the most hazy pixels. Most hazy pixel in input hazy image is selected and each color channel of an input image filtered with a ordinary non linear filter with moving window. Then the maximum value of each color channel is estimated.

Boundary constraints of the image are calculated. The scene radiance of the image is surrounded, that is,

$$C_0 \leq J(X) \leq C_1 \quad (1)$$

Where, $C_0$ and $C_1$ are constant vectors of the given input image.

Some pixels share a similar depth value in a local image patch. In addition patch-wise transmission from the boundary constraint is derived. However, abrupt depth jumps occur in some situations that leads to failure in contextual consideration and resulting in considerable halo artifacts in the De-hazed images. Introduction of a weighting function W(x, y) on the constraints overcomes the problem. Consequently Weighted$L1$-norm based contextual regularization is implemented. The incorporated filter banks helps to attenuate the noises in the image and improves corners and jump edges. Transmission function is estimated using the following formula,

$$t(x) = F^{-1}\left(\frac{\frac{\lambda}{\beta}F(\widehat{t}) + \sum_{j\epsilon w}\overline{F(D_j)}.\ F(u_j)}{\frac{\lambda}{\beta} + \sum_{j\epsilon w}\overline{F(D_j)}.\ F(D_j)}\right)$$

(2)

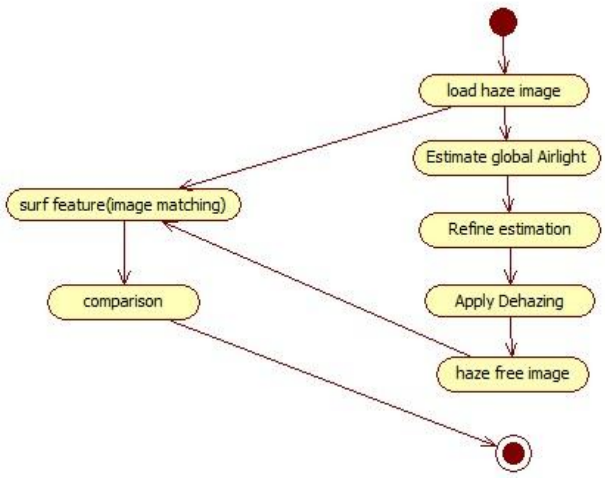



**Fig 1. Flow diagram of haze removal**

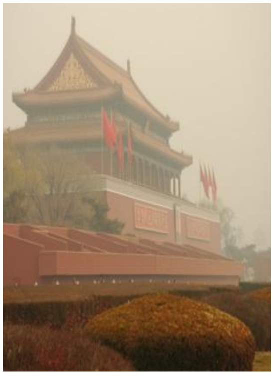
The fig 1 explains the process involved in the haze removal process. The air light is estimated from the given input image by selecting the most hazy pixel. The boundary constraints and cal transmission are calculated. The estimated air light is subtracted from the foggy image and divided y the estimated transmission value to obtain a dehazed image.

## V. RESULTS AND DISCUSSIONS

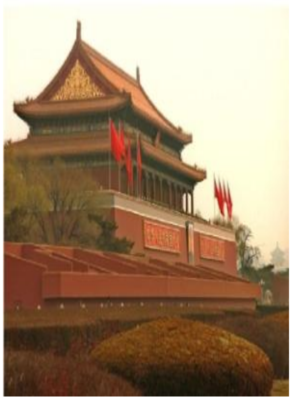
The experiment is conducted with the data set of 22 hazy images for the analysis. The figure from 2 and 3 shows the various processes involved in haze removal from an image. Mean square error (MSE) and peak signal to noise ratio (PSNR) are calculated for the quantitative analysis.

**Table-I Performance Metric**

| Measure | Definition | Parameters |
|---|---|---|
| MSE | $\frac{1}{M \times N} \sum_{(i,j)=1}^{M \times N} (f(i,j) - g(i,j))$ ∧ 2 | f(i,j)-Original image g(i,j)-Filtered image |
| PSNR | 10*log10((255*255)/MSE) | MSE- mean square Error |

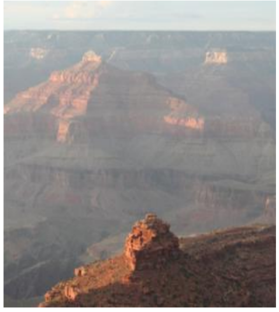


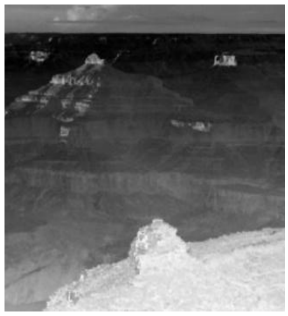
**(a)Input Image** **(b)Boundary Constraints**



**(c) Transmission Mapping** **(d)Output Image**

**Fig 2. Steps invloved in proposed method (Contextual regularization)**





**(a)Input Image** **(b)Boundary Constraints**

**(c) Transmission Mapping** **(d) Output Image**

**Fig 3. Steps invloved in proposed method (Contextual regularization)**

The Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR) are the two important parameters applied to compare the quality of the images obtained from various methods. The MSE represents the cumulative squared error between the dehazed image and the foggy image, whereas PSNR represents the measure of the peak error. Table II and III gives the comparison of MSE and PSNR values. The proposed method shows lower value of MSE and higher value of PSNR in comparison with other methods.

**Table-II Mean Square Value**

| Image Id | Existing Method (Guided Filter) | Existing Method (Dark Channel Prior) | Proposed Method (Contextual Regularization Method) |
|---|---|---|---|
| Img 001 | 222.08 | 199.13 | 109.85 |
| Img 015 | 214.38 | 196.65 | 121.19 |
| Img 044 | 239.85 | 239.79 | 227.31 |
| Img 006 | 151.48 | 154.59 | 118.26 |
| Img 004 | 240.16 | 203.57 | 190.38 |
| Img 028 | 246.87 | 150.23 | 92.35 |
| Img 050 | 175.46 | 103.41 | 69.63 |

**Table-III Peak Signal to Noise Ratio**

| Image Id | Existing Method (Guided Filter) | Existing Method (Dark channel prior) | Proposed method (Contextual regularization method) |
|---|---|---|---|
| Img 001 | 24.69 | 25.17 | 27.75 |
| Img 015 | 24.85 | 25.22 | 27.33 |
| Img 044 | 24.36 | 24.36 | 24.59 |
| Img 006 | 26.36 | 26.27 | 27.43 |
| Img 004 | 24.35 | 25.07 | 25.36 |
| Img 028 | 24.24 | 26.39 | 28.51 |
| Img 050 | 25.72 | 28.01 | 29.73 |

Fig 4 and Fig 5 shows the pictorial representation of Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR). The proposed method shows better results in comparison with existing methods. Thus, the enhanced output is obtained with the proposed method.

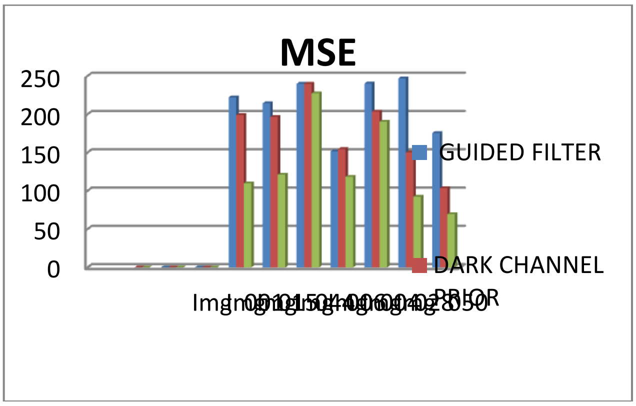



**Fig 4. Mean Square Error**

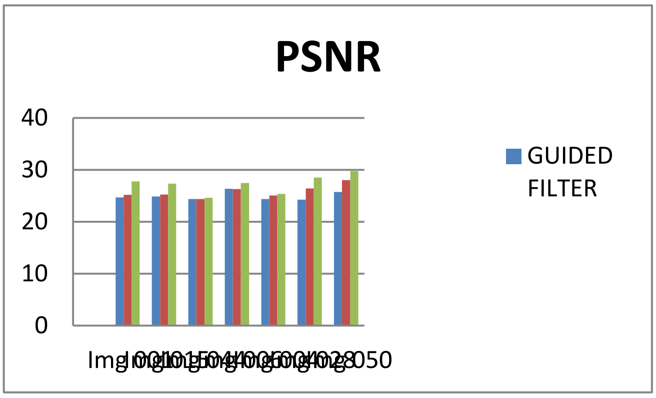



**Fig 5. Peak Signal to Noise Ratio**

## VI. CONCLUSION

In foggy conditions, images become distorted due to scattering of light by fog. Subtraction of estimated air light map from degraded image produces a effective dehazed image. The air light map is obtained with multiple linear regressions, which establishes the relationship between regional air light and the coordinates of the image pixels. On the basis of both quantitative and qualitative analysis, the restoration results produced by this method is more efficient the existing methods. In future, haze removal from the video captured in real time can be implemented. this can abruptly reduce the number of road accidents.

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