Improved Haze Removal Method using Proportionate Fusion of Color Attenuation Prior and Edge Preserving

Sudeep D. Thepade
Dept. of Computer Engineering
Pimpri Chinchwad College of Engg.
SPPU,Pune, India
sudeepthepade@gmail.com

Pratibha Mishra
Dept. of Computer Engineering
Pimpri Chinchwad College of Engg.
SPPU,Pune, India
p4pratibha.mishra412@gmail.com

Rucha Udgirkar
Dept. of Computer Engineering
Pimpri Chinchwad College of Engg.
SPPU,Pune, India
ruchaudgirkar@gmail.com

Sahil Singh
Dept. of Computer Engineering
Pimpri Chinchwad College of Engg.
SPPU,Pune, India
sahilsuman9575@gmail.com

Poonam Mengwade
Dept. of Computer Engineering
Pimpri Chinchwad College of Engg.
SPPU,Pune, India
poonam.mengawade@gmail.com

Abstract*—Nowadays, fog and haze are becoming a global challenge. Images captured under the hazy condition have poor contrast and corrupted colour. Such images limit the visibility and thus hinder the way for the computer vision purposes like video observation, entity recognition. Such hazy images affect the usual working in the transportation sector e.g. trains, ships etc. One of the prominent factors affecting the outdoor vision applications is poor vision and thus, it may result in an intangible loss like safety. The image captured shows this behaviour because of the air light. This paper analyses the widely used techniques for haze removal from images alias color attenuation prior based haze removal and haze removal with edge preserving. Also, the paper proposes the better haze removing techniques using fusion based approach which gives better quality haze removal compared to the bench mark haze removal techniques. Experimental results tested with NIQE have proved the worth of proposed methods.

***Keywords*— haze; transmission map; image fusion; edge preserving; dehazing; air-light**

I. Introduction

Image quality is degrading because of poor weather conditions such as smog, fog, haze etc. Outdoor images usually loose contrast. When picture is taken using camera in presence of haze the light gets scattered due to the water droplets, dust etc. before reaching the camera which makes the image blur and degrades its quality. Existing haze removal systems are based on certain calculations, environmental conditions are estimated e.g. Atmospheric light or degree of the haze level. Most of these automatic systems which depend on the input images, fail, here because of the degraded image quality. Analyzing the current widely used techniques and performing the comparative study, it is easy to select the best haze removal technique under different environmental conditions and also as per the requirement specification. Even two of the most popular haze removal methods such as color attenuation prior and edge preserving have the drawbacks like darkening of images and over edging respectively.

In physical model-based haze removal techniques the complexity is generally high and thus they are taking more time for the calculations, unknown parameters need to be assumed as constants. In non-physical model-based haze removal techniques, image enhancement or restoration is basically performed. The strategy for haze removal can be classified into two ways – Image enhancement and Image restoration. Image enhancement techniques do not include the reason behind the degrading of the image. It just enhances the input image. Image restoration techniques preserve the originality of the input image. Haze removal techniques will be in the demand for the future as most of the computer vision applications need a clear picture to process it whether that is surveillance, security etc. Also the performance improvement of the grascle image colorization [1, 2], retrieval [3,4], classification [5, 6], panoramic view creation [7, 8] may be achieved using the haze removed images. In biometric identification [9,10,11,12] haze removal may be used as pre-processing technique for better identification accuracy.

II. Literature Survey

In literature, lot of haze removal techniques have been proposed. Haze removal can be classified on the basis of number of input images given i.e. single image and multiple image haze removal. Various methods are introduced to deplete the haziness from the image using multiple images or some additional information, one such method is polarization [13]. The Methods which are based on Polarization removes the effect of haze through two or more than two images taken with different degrees of polarization. But in the recent times single image haze removal is the trend as it is more efficient and reliable.

The paper discusses the single image haze removal technique Dealing with images at the base level means dealing or manipulating the pixel values of the image. Various techniques have been introduced to overcome the degradation of image quality based on certain parameter like atmospheric light, transmission map etc. Some of the widely used methods for haze removal are fusion based [14] filtering based color attenuation, edge preserving. Many authors have published their study and work on this topic [15].

Qingsong Zhu, Jiaming Mai, and Ling Shao have proposed haze removal method[16]from a single input hazy image using simple but powerful color attenuation prior[16].

Kaiming He, Jian Sun and Xiaoou Tang have proposed haze removal method which is a simple and effective image dehazing approach i.e. Dark Channel Prior is proposed [17].

Zhengguo Li have proposed Edge-preserving decomposition-based method [18] to estimate the transmission map so as to produce a more clear haze free image, while preserving the edges [18].

Ritu Singh and Mantosh have proposed Image fusion methods that are used to fuse two or more hazy images[19]. Techniques like color attenuation prior deals with the concentration of haze and depending on that it dehazes the image [15]. Dark Channel prior can estimate the transmission map more accurately.

Another technique that is primarily used to preserve the edges of the input hazy images while applying various filters is edge preserving technique [15,18]. Fusion techniques are used to fuse different images and produce a more clear and modified image. Dark channel Prior, Bilateral Filter, Trilateral Filter are used for visibility restoration. Some of the widely used methods for haze removal are briefly discussed in Haze removal [16].

III. EXISTING METHODS

There are various existing methods which removes the haze from the image. Dark Channel Prior (DCP) is Single image dehazing approach. The dark channel prior works on outdoor haze-free images [16]. DCP is based on the Dark Pixel which is available in most local patches in outdoor haze-free images contain some pixels whose intensity is very low, in at least one color (RGB) channel [17].

This approach is physically valid and works well in dense haze. DCP increase the contrast of image and maintains color reliability [17]. It also works on greyscale images if shadow is not present. As Dark Channel Prior is time consuming process, so number of unnecessary step can be removed to make Dark Channel Prior work faster [17].
Image fusion technique is used to fuse two de-haze images. In this method, we make use of Weight Maps to improve to quality of the Image. Image fusion can be applied on multiple as well as single Image [19]. But single Images are considered to be the most informative and accurate. Image Fusion can be applied for indoor and outdoor images [14].

A. COLOR ATTENUATION PRIOR BASED HAZE REMOVAL[16]

It is novel linear method which is based on difference of brightness and saturation of the pixels within the hazy images. To recover the dehazed image, color attenuation first identifies or estimates certain attributes related to input image provided [15,16]. The color attenuation-based haze removal methods have five steps i to iv as elaborated here.

i. Atmospheric Scattering Model

Mc Cartney proposed an atmospheric scattering model to describe the hazy image [20]. The equation of atmospheric scattering model is mentioned below.

$$I(x) = J(x)t(x) + A(1 - t(x)) \qquad (1)$$

$$t(x) = e{-}\beta d(x) \qquad (2)$$

Here I is the hazy image, J is the scene radiance, A is atmospheric light, β is scattering coefficient, x is the position of pixel, t is transmission medium, also I, J, K represents the three-dimensional vectors in RGB. T can be calculated using the 2nd equation if depth is given.

It is observed that in normal images i.e. haze free images; the brightness is moderate whereas the saturation is high. But in the case of hazy images its inverse. In hazy images the brightness is high, and saturation is extremely low which makes the image appear white. Based on many experiments it is found that concentration of haze depends on the difference of brightness and saturation [21].

The equation1 is the one which whole color attenuation process works.

$$d(x) \propto c(x) \propto v(x) - s(x) \qquad (3)$$

Where d, c, v, s represents depth, concentration of haze, brightness, saturation respectively This is a linear model i.e. here depth, concentration of haze and difference of brightness and saturation are linearly dependent on each other.

$$d(x) = \theta_0 + \theta_1 v(x) + \theta_2 s(x) \qquad (4)$$

Here d, v, s represents depth, brightness, saturation.
To prove the above equation gradient of d is calculated.

$$\nabla d = \theta_1 \nabla v + \theta_2 \nabla s \qquad (5)$$

Since brightness and saturation are two single channel images into which I i.e. the hazy images is split, equation (5) confirms that d has only one edge in I due to which it can be stated that “This linear model emphasis the edge preserving property by which the depth information can be well recovered even near the depth discontinuities in the scene.” This linear model works very well [15,16,21].

ii. Estimation of linear coefficient matrix:

To estimate the linear coefficients in equation (4) ***(θ_0, θ_1, θ_2)*** supervised learning is used. The training data contains the hazy image and ground truth map associated with it. When the values of the coefficients are determined, they can be used for any single hazy image. For recovering the scene depth of the hazy image their parameters will be used [15,16].

iii. Estimation of depth information

Using the linear equation (4), depth map can be obtained. Transmission map can also be recovered with this method. Using this both depth map and transmission map dehazing become easier.

iv. Estimation of atmospheric light

Although the depth map of the input hazy image has been recovered, the distribution of the scene depth is known. For representing distant places bright regions in the map are used.

v. Scene Radiance recovery

However, the depth of the scene d and the atmospheric light are known, transmission t can be easily estimated, and J can be recovered. Now that the depth and atmospheric light are known transmission t(x) can be estimated easily. As the equation (1) and equation (2) is used, the scattering coefficient determines the intensity of dehazing indirectly. To avoiding too much noise, the value of the transmission t(x) is restricted between 0.1 and 0.9.

B. EDGE PRESERVING BASED HAZE REMOVAL[18]

While removing the haze from the image, the most prominent factor that affects the image quality is the edges. Therefore, need arises to preserve the edges in the improved image. Edge preserving techniques uses filters like bilateral filter, weighted guided image filter (WGIF)[20], guided image filter (GIF) etc. Each filter has its own advantages and limitations [18]. Bilateral filter is used because of its simplicity. In GIF and WGIF[20] guidance image is used, it helps to reconstruct the degraded image, generally the guided image is identical to the original image [22,23].
Modified Edge preserving techniques using different filters generally follows described steps i to iii here.

i. *Estimation of Transmission Map:*

A raw transmission map is created based on the input image without using Dark Channel Prior. Transmission map describes the details in the image. It provides base layer and detail layer.

ii. *Refining of transmission map:*

The transmission map obtained is not adequate to get the filtered output, hence guided filter is applied so as to refine the obtained transmission map. Guided filter will use a guidance image to create a de hazed image. Guidance image could be similar to input image or any other image. It will smoothen the image along with edge preservation.

iii. *Recover the Output Image:*

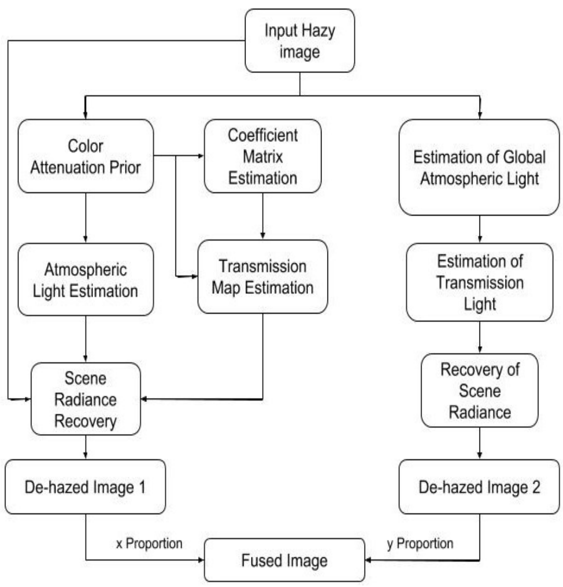
To finally acquire the output image, the processed image is finally refined using matting Laplacian and de hazed image is obtained.

IV. Proposed System

From the existing haze removal methods, it is clear that Color Attenuation based haze removal method works for the sky images but gives blurred dehazed images which are little darker where detailing is not coarticulated. Similarly, the edge preserving based image dehazing do not blur the dehazed images, but result is over edging. Proposing system tries to select the advantages of both existing methods and apply them all together to produce better dehaze images.

The proposed system will use edge preserving methods as well as color attenuation technique. Reason is, edge preserving tries to preserve the edges of the input images, which makes the output image more perspicuous. Similarly, color attenuation technique helps to preserve the natural color of the input image. Thus, the proposed system generates a result that is easier to perceive and understand.

Fig. 1 : Block Diagram of Fusion based haze removal method using Color Attenuation Prior and Edge Preserving.



Here, first dehazed image is the output of Color Attenuation Prior whereas the second is the output of Edge Preserving. Both the outputs are fused in a certain proportion. Using the existing methods, we have modelled three sets. The sets are in the ratios 30(x)-70(y), 40(x)-60(y), 45(x)-55(y). Where x is output image of color attenuation prior and y is output image of edge preserving.

V. Experimentation Environment

To validate the performance of the proposed method a set of hazy images is used as shown in the testbed. Based on this testbed in fig.2, the experimental results are evaluated.

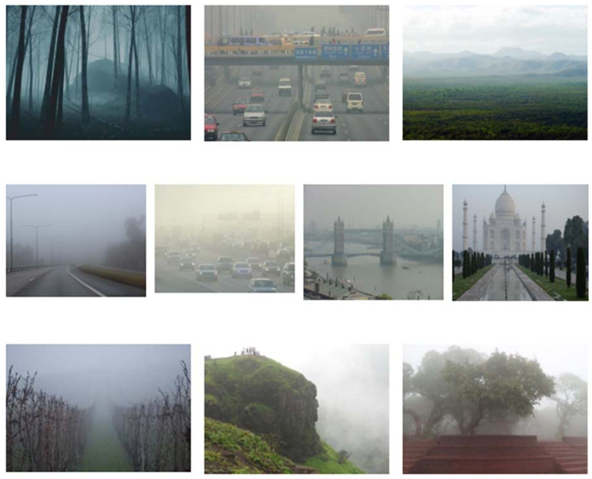
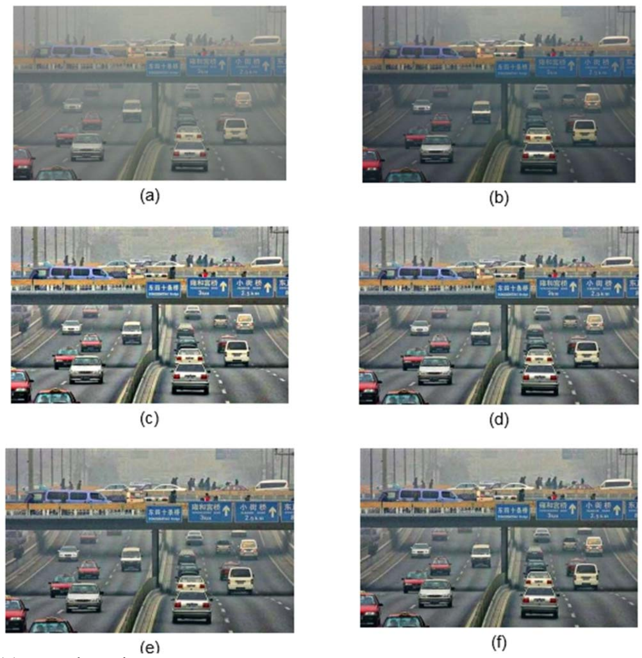


Fig. 2: Testbed of Hazy Images.

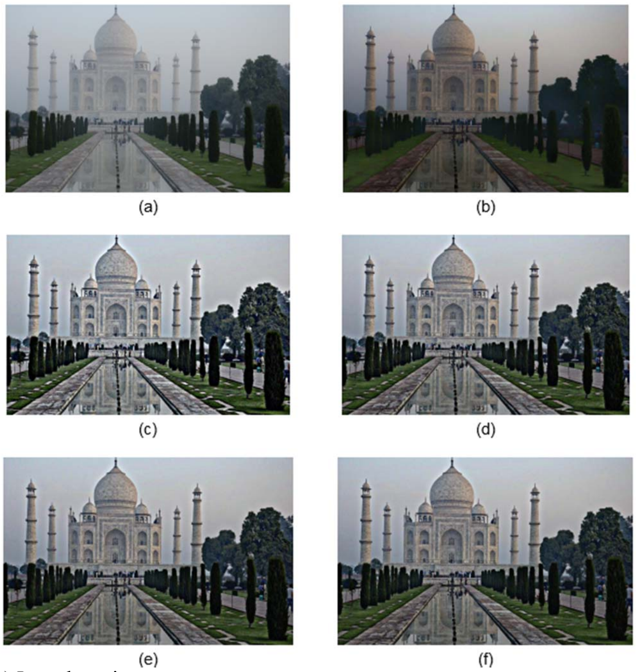
VI. Results And Discussion

All the implementation of the existing as well as the proposed methods are done in MATLAB.



(a) Input hazy image.
(b)Result of Color Attenuation Prior based dehazing [16]
(c)Result of Edge Preserving based dehazing [18].
(d)Proposed fusion based dehazing with 30-70 proportion of Color Attenuation Prior and Edge Preserving.
(e) Proposed fusion based dehazing with 40-60 proportion of Color Attenuation Prior and Edge Preserving.
(f) Proposed fusion based dehazing with 45-55 proportion of Color Attenuation Prior and Edge Preserving.

Fig.3: Comparison of proposed fusion based haze removal method with existing method for sample image 1.



(a) Input hazy image.
(b)Result of Color Attenuation Prior based dehazing [16]
(c)Result of Edge Preserving based dehazingk[18].
(d)Proposed fusion based dehazing with 30-70 proportion of Color Attenuation Prior and Edge Preserving.
(e) Proposed fusion based dehazing with 40-60 proportion of Color Attenuation Prior and Edge Preserving.
(f) Proposed fusion based dehazing with 45-55 proportion of Color Attenuation Prior and Edge Preserving.

Fig. 4: Comparison of proposed fusion based haze removal method with existing method. for sample image 2

Figure 3 and 4 gives results for comparative analysis of haze removal methods of existing methods [16] and [18] with the proposed proportionate fusion based technique with help of sample image1 and sample image 2 respectively. It is visually perceived that amongst the obtained output images from different methodologies, the output of the proposed methods overcome the demerits of the existing methods.

TABLE I. NIQE BASED PERFORMANCE COMPARISON OF EXISTING AND PROPOSED HAZE REMOVAL METHODS

Image No.	Color Attenuation prior (x)[6]	Edge Preserving(y)[3]	Fusion with 30 - 70	Fusion with 40-60	Fusion with 45 - 55
1	2.92533	2.40007	2.39411	2.34216	2.38152
2	3.04324	3.16995	3.11155	3.18693	3.14438
3	3.20481	3.13195	3.14590	3.20073	3.23166
4	3.78889	2.87493	2.76381	2.76038	2.74221
5	3.58865	3.72887	3.73252	3.56648	3.53027
6	3.22554	2.83287	2.88501	2.92573	2.85348
7	3.25008	2.65039	2.37739	3.52444	2.63205
8	9.92083	8.82504	8.21104	8.30766	8.69155
9	3.08354	3.44029	3.01360	2.99935	2.92500
10	2.71575	3.26834	2.97185	3.03149	2.98050
NIQE Average	3.89467	3.63227	3.45618	3.48455	3.51126

This paper evaluates the image quality using NIQE scores/model. Firstly, NIQE model is trained based on the input hazy images, with respect to that model NIQE score is calculated and shown

NIQE(I) uses Naturalness Image Quality Evaluator and calculates the no-reference image quality score for image. NIQE compares image to a Trained model computed from images of natural scenes. A smaller score will indicate perceptual quality [24]. The score = NIQE(D, model) calculates the image quality score by making use of custom model [24].

Table 1 and Fig. 5 gives performance comparison of the proposed fusion based haze removal methods with existing haze removal using color attenuation [6] and haze removal using edge preserving [18]. Using NIQE measure the average NIQE values indicate that the quality of dehazed images with proposed fusion based image haze removal methods is better as compared to existing method.

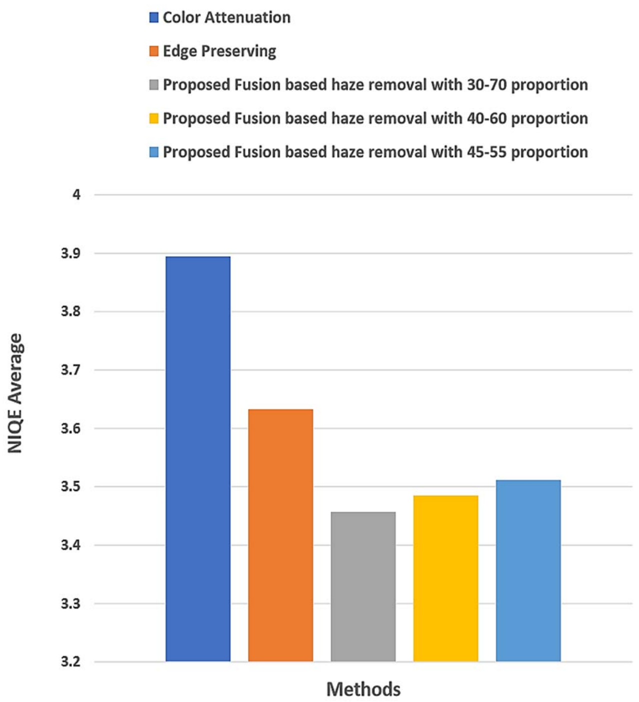


Fig.5 Average NIQE based performance comparison of existing and proposed haze removal methods.

The problems present in dehazed images with existing methods like low contract, overfitting, overedging, blurring is not evidently observed in the dehazed images of proposed fusion based dehazing methods.

VII. CONCLUSION

Haze removal from images provides many applications in various areas or fields. Haze removal algorithms are more useful for remote sensing, navigation, object detection, satellite image identification, and many vision applications. The paper has studied existing algorithms that has been developed to remove haze. But there are some drawbacks in the existing methods which has been discussed and a better haze removal technique is proposed to overcome the existing haze removal methods limitations using fusion based approach. To achieve the expected result, the color attenuation prior and edge preserving haze removal methods are fused with certain proportions to get novel fusion based better haze removal method. According to the experimentation results it is proved that given proposed method is giving better NIQE score despite other used existing methods. The output images generated using proposed method avoids overfitting, lose contrast, end preserves the natural colour of the image and enhances the overall image quality proving worth of proposed fusion based haze removal methods.

REFERENCES

[1] H. B. Kekre, Sudeep D. Thepade, Archana Athawale, Adib Parkar,"Using assorted color spaces and pixel window sizes for colorization of grayscale images", Proceedings of ACM International Conference and Workshop on Emerging Trends in Technology,2010

[2] H.B. Kekre, Sudeep D. Thepade, "Colorization of Grayscale Images using Kekre's LUV Color Space", Proc. of National Level Technical Paper presentation Competition THINKQUEST-2009

[3] Sudeep D Thepade, Krishnasagar S Subhedarpage, Ankur A Mali, "Performance Rise in Content Based Video Retrieval using Multi-level Thepade's sorted ternary Block Truncation Coding with intermediate block videos and even-odd videos", IEEE International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2013

[4] H. B. Kekre, Sudeep D. Thepade, Varun K Banura,"Amelioration of colour averaging based image retrieval techniques using even and odd parts of images", International Journal of Engineering Science and Technology (IJEST), Volume 2, Issue 9, 2010

[5] Sudeep Thepade, Rik Das, Saurav Ghosh, "A novel feature extraction technique using binarization of bit planes for content based image classification", Hindwai Journal of Engineering, 2014, http://dx.doi.org/10.1155/2014/439218

[6] Neha R Kasat, Sudeep D Thepade, "Novel content based image classification method using lbg vector quantization method with bayes and lazy family data mining classifiers", 7th International Conference on Communication, Computing and Virtualization , Elsevier Procedia Computer Science 79, 2016

[7] H. B. Kekre, Sudeep D. Thepade, "Rotation Invariant Fusion of Partial Image Parts in Vista Creation using Missing View Regeneration", WASET International Journal of Electrical Computer and Systems Engineering (IJECSE), Volume 2, Issue 2, 2008

[8] H. B. Kekre, Sudeep D. Thepade, "Panoramic View Construction using Partial Images", IEEE sponsored International Conference on Sensors, Signal Processing, Communication, Control and Instrumentation (SSPCCIN-2008)"

[9] H. B. Kekre, Sudeep D. Thepade, Akshay Maloo , "Performance Comparison for Face Recognition using PCA, DCT &WalshTransform of Row Mean and Column Mean", ICGST International Journal on Graphics, Vision and Image Processing (GVIP), volume 10, Issue II, 2010

[10] H. B. Kekre, Sudeep D. Thepade, Akshay Maloo,"Face Recognition using Texture Features Extracted from Walshlet Pyramid", ACEEE International Journal on Recent Trends in Engineering and Technology (IJRTET), Volume 5, Issue 1, 2011

[11] Sudeep D Thepade, Pooja Bidwai, "Iris recognition using fractional coefficients of transforms, Wavelet Transforms and Hybrid Wavelet Transforms", IEEE International Conference on Control Computing Communication & Materials (ICCCCM), 2013

[12] Manisha Madane, Sudeep D. Thepade, "Score Level Fusion Based Bimodal Biometric Identification Using Thepade's Sorted n-ary Block Truncation Coding with Variod Proportions of Iris and Palmprint Traits", 7th International Conference on Communication, Computing and Virtualization , Elsevier Procedia Computer Science 79, 2016

[13] E. J. McCartney, "Optics of the Atmosphere: Scattering by Molecules and Particles." New York, NY, USA: Wiley, 1976.

[14] Guangyi Yang, Yue Liao, Qingyi Zhang, Deshi Li,and Wen Yang,,"No-Reference Quality Assessment of Noise-Distorted Images Based on Frequency Mapping", October 18, 2017.

[15] Codruta Orniana Ancuti and Philippe Bekaert)"Effective Single Image Dehazing By Fusion" (Proceedings of 2010 IEEE 17 th International Conference on Image Processing September 26-29,2010, Hong Kong.

[16] A.Abiraha,E.Moogambiga,T.Mathubala, 2016,'An Effective Haze Removal algorithm Using Color Attenuation Prior Model', International Conference on Emerging Engineering Trends and Science.

[17] Kaiming He, Jian Sun,and Xiaoou Tang, fellow IEEE,12, DECEMBER 2011"Single Image Haze Removal Using Dark Channel Prior" IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, VOL. 33.

[18] K. He, J. Sun, and X. Tang, "Guided image filtering," IEEE Trans. Pattern Anal. Mach. Intell., vol. 35, no. 6, pp. 1397–1409, Jun. 2013Boyang Qin, Zhitong Huang, Fanxiang Zeng, Yuefeng Ji , "Fast Single Image Dehazing with Domain Transformation-based Edge Preserving Filter and Weighted Quadtree Subdivision",2015

[19] Y.Y.Schechner,S.G.Narasimhan,and S.K Nayar,"Instant Dehazing of Images using Polarization,", Proc. IEEE Conf. Computer Vision and Pattern Recognition,vol.1,pp.323-332,2001

[20] Zhengguo Li and Jinghong Zheng," Edge-Preserving Decomposition-Based Single Image Haze Removal", IEEE transactions on image processing, vol. 24, no. 12, December 2015.

[21] Ya-bing Zhu, Jun-min Liu, Ying-guang Hao,"An Single Image Dehazing Algorithm Using Sky Detection and Segmentation",The 2014 7th International Congress on Image and Signal Processing.

[22] Zainab Khan,Dr. Anjali Ashish Potnis,"Image Haze Removal Using Image Visibility Restoration & Edge Preserving Decomposition",2017.

[23] Qingsong Zhu, Jiaming Mai, and Ling Shao, 2015,'A Fast Single Image Haze Removal Algorithm Using Color Attenuation Prior', IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 24

[24] Ritu Singh and Mantosh, "Contrast and Color Improvement Based Haze Removal of UnderwaterImages Using Fusion Technique", (4th IEEE International Conference on Signal Processing,Computing and Control (ISPCC 2k17), Sept 21-23,2017,Solan,India)