International Journal of Computer Engineering and Applications, Volume VII, Issue III, September 14

MODIFIED HAZE REMOVAL USING DARK CHANNEL PRIOR, GABOR FILTER & CLAHE ON REMOTE SENSING IMAGES

Er. Harpoonamdeep Kaur [1], Dr. Rajiv Mahajan [2]

[1,2] Computer Science Department, G.I.M.E.T Asr

ABSTRACT:

Haze removal techniques denotes to the approaches which are utalized for restoring the perceptibilityof the digital picture utalizing some rebuilding stratergies. The degradation may be a result of diverseexplanationslike relative object-camera motion, misrepresentationof camera miss-focus,twisting due to Polaroid miss-center, relative climatic turbulence and others.This paper has focused on diverse haze clearing strategies. Haze removal has found to be a serious assignment in light of the way that the mist depends on the unidentified scene depth data.Mist impact is the capacity of separation in the middle of camera and item. Henceforth evacuation of haze requires the estimation of air light map.The specialists has overlooked the methods to decrease the noise issue which is displayed in the yield pictures of the current haze evacuation algorithm furthermore, no work has focused on the coordinated effort of the Dark channel prior and the CLAHE. The issue of irregular light is likewise disregarded. So this exploration work has proposed another mist evacuation model to proficiently lessen the impact of the haze from computerized pictures.

Keywords: Fog removal, image enhancement, visibility restoration.

[1] INTRODUCTION

Visibility restoration [1] refers to different methods that aim to reduce or remove the degradation that have occurred while the digital image was being obtained. The degradation may be due to various factors like relative object-camera motion, blur due to camera misfocus, relative atmospheric turbulence and others. In this we will be discussing about the degradations due to bad weather such as fog, haze, rain and snow in an image. The image quality of outdoor screen in the fog and haze weather condition is usually degraded by the scattering of a light before reaching the camera due to these large quantities of suspended particles (e.g. fog, haze, smoke, impurities) in the atmosphere. This phenomenon affects the normal work of automatic monitoring system, outdoor recognition system and intelligent transportation system. Scattering is caused by two fundamental phenomena such as attenuation and airlight. By the usage of effective haze removal of image we can improve the stability and robustness of the visual system. Haze removal is a tough task because fog depends on the unknown scene depth information. Fog effect is the function of distance between camera and object. Henceremoval of fog requires the estimation of airlight map or depth map. The current haze removal method can be divided into two categories: image enhancement and image restoration. Image enhancement does not include the reasons of fog degrading image quality. This method can improve the contrast of haze image but loses some of the information regarding image. Image restoration firstly studies the physical process of image imaging in foggy weather. After observing that degradation model of fog image will be established. At last, the degradation process is inverted to generate the fog free image without the degradation. So, the quality of degraded image could be improved.

[1.1] VISIBILITY RESTORATION TECHNIQUE

For removing haze, fog, mist from the image various technique are used. Typical methods of image restoration to the fog are:

A. Dark channel prior : Dark channel prior [2] is used for the estimation of atmospheric light in the dehazed image to get the more proper result. This technique is mostly used for non-sky patches, as at least one color channel has very low intensity at some pixels. The low intensity in the dark channel are predominantly because of three components:-

- Colourful items or surfaces(green grass, tree, blooms and so on)
- Shadows(shadows of car, buildings etc)
- Dark items or surfaces(dark tree trunk, stone)

As the outdoor images are usually full of shadows and colorful, the dark channels of these images will be really dark. Due to fog (airlight), a haze image is brighter than its image without haze. So we can say dark channel of haze image will have higher intensity in region with higher haze. So, visually the intensity of dark channel is a rough approximation of the thickness of haze. In dark channel prior we also use pre and post processing steps for getting better results. In post processing steps we use soft matting or bilateral filtering etc. Let J(x) is input image, I(x) is foggy image, t(x) is the transmission of the medium. The attenuation of image due to fog can be expressed as:

$$I_{att}(x) = J(x)\mathrm{t}(\mathrm{x}) \qquad (1)$$

the effect of fog IS Airlight effect and it is expressed as:

$$I_{airlight}\,(x) = \ A(1 - t(x)) \qquad (2)$$

Dark channel for an arbitrary image J, expressed as J dark is defined as:

$$J^{dark}(x) = \frac{min}{y \in \Omega(x)}(\min J^{C}\,(Y)) \qquad (3)$$

In this Jc is color image comprising of REG components, !lex) represents a local patch which has its origin at x. The low intensity of dark channels is attributed mainly due to shadows in images, saturated color objects and dark objects in images.

After dark channel prior, we need to estimate transmission t(x) for proceeding further with the solution. Another assumption needed is that let Atmospheric light A is also known. We normalize (4) by dividing both sides by A:

$$\frac{I^c}{A^c}(x) = t(x)\frac{J^c}{A^c}(x) + 1 - t(x) \qquad (4)$$

B. CLAHE : Contrast limited adaptive histogram equalization short form is CLAHE [3]. This method does not need any predicted weather information for the processing of hazed image. Firstly, the image captured by the camera in foggy condition is converted from RGB (red, green and blue) color space is converted to HSI (hue, saturation and intensity) color space. The images are converted because the human sense colors similarly as HSI represent colors.Secondly intensity component is processed by CLAHE without effecting hue and saturation. This method use histogram equalization to a contextual region. The original histogram is clipped and the clipped pixels are redistributed to each gray-level. In this each pixel intensity is shortened to maxima of user selectable. Finally, the image processed in HSI color space is converted back to RGB color space.

Figure 1: (a) input image

Figure 1: (b) output image

C. Wiener filtering : Wiener filtering is based on dark channel prior: Wiener filtering [4] is used to counter the problems such as color distortion while using dark channel prior when the images with large white area is processed.

While using dark channel prior the value of media function is rough which create halo effect in final image. So, median filtering is used to estimate the media function, so that edges can be preserved. After making the median function more accurate it is combined with wiener filtering so that the image restoration problem is transformed into optimization problem. This algorithm is useful to recover the contrast of a large white area for image. The running time of image algorithm is also less.

Figure 2: (a) Original foggy image (b) Defogged image (c) Weiner defogged image

D. Bilateral filtering : This filtering [5] smooth's images without effecting edges, by means of a non-linear combination of nearby image values. In this filter replaces each pixel by weighted averages of its neighbour's pixel. The weight assigned to each neighbour pixel decreases with both the distance in the image plane and the distance on the intensity axis. This filter helps us to get result faster as compare to other. While using bilateral filter we use pre-processing and post processing steps for better results. Histogram equalization is used as pre-processing and histogram stretching as a post processing. These both steps help to increase the contrast of image before and after usage of bilateral filter. This algorithm is independent of density of fog so can also be applied to the images taken in dense fog. It does not require user intervention. It has a wide application in tracking and navigation, consumer electronics and entertainment industries.

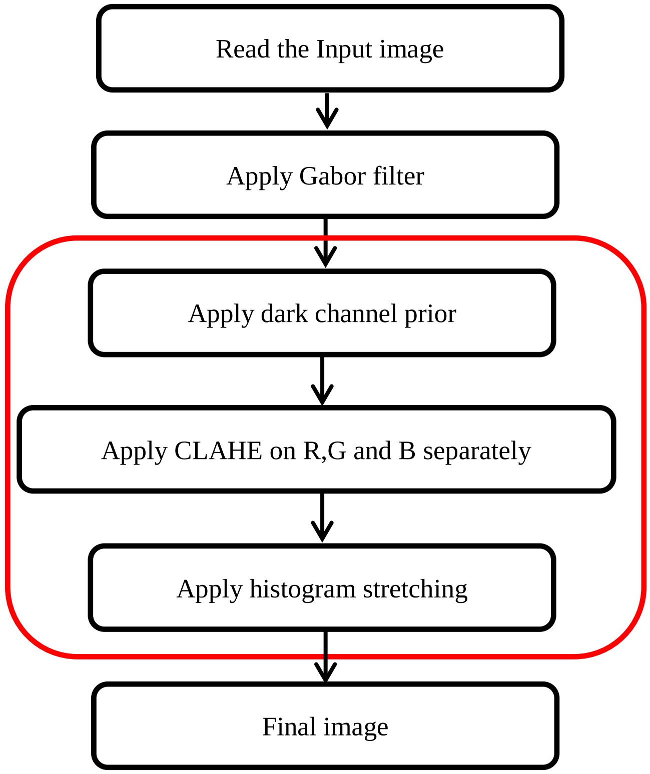
Figure 3: (a) original foggy 'pumpkins' image, (b) corresponding air light map using bilateral filter, and (c) Restored image

[2] LITERATURE SURVEY

Tae Ho Kil et al. (2013)[6] has proposed the dehazing procedure constructed on dark channel prior and contrast enrichment methods. The orthodox dark channel prior scheme eradicates the haze and thus restores the colors of the objects in the view, but it does not take into account the improvement of image contrast. E. Ullah et al. (2013) [7] evaluated that environmental conditions such as haze, fog or rain noticeably affects the visibility. The water droplets existing in the atmosphere produce mist, fog and haze results due to dispersion of light as it circulates through these particles. These chromatic effects of image dispersion can be reversed for recovery of image knowledge. Muhammad SuzuriHitamet.al. (2013) [8] has evaluated a new method called mixture Contrast Limited Adaptive Histogram Equalization (CLAHE) color models that exactly established for underwater image improvement. The technique works CLAHE on RGB and HSV color models and the results are joint together using Euclidean norm. The proposed method significantly improves the visual quality of underwater images by enhancing contrast, as well as reducing noise and artifacts.Abhishek Kumar Tripathi et al. (2012) [5] has examined a novel and effective fog removal algorithm. The algorithm practices bilateral filter for the approximation of air-light. By way of the given process is free from the concentration of fog and don't entail user interference. It can tackle both color as well as gray images. F-C. Cheng et al. (2012) [10]has discussed that the lowest level channel prior for effective image fog removal. The use of the lowest level channel is simplified from the dark channel prior. It is based on a key observation that fog-free intensity in a color image is usually the minimum value of trichromatic channels. To estimate the transmission model, the dark channel prior then performed as a min filter for the lowest intensity. A.K. Tripathi and S. Mukhopadhyay (2012) [11] have proposed a novel and efficient fog removal algorithm. The fog formation is because of the attenuation and the air-light i.e. the attenuation reduces the contrast and air-light increases the whiteness in the scene. Single image fog removal using anisotropicdiffusion uses an anisotropic diffusion to recover a scene contrast. YanjuanShuai et al. (2012) [4] has studied that, with the use of the image haze removal of dark channel prior, one is prone to color distortion phenomenon for some wide white bright part in the image. An image haze removal of wiener filtering based on dark channel prior has been proposed. The proposed algorithm can recapture the contrast of a big white area of foggy image and compensates for the lack of dark channel prior algorithm.HaoranXu et al. (2012) [2] after a profound study on the haze removal technique of single picture over quite a while has actualized a quick haze evacuation algorithm, in light of fast bilateral filtering aggregated with dark colors prior. The calculation begins with the barometric scattering model, infers an expected transmission map utilizing dark channel prior, and afterward consolidates with gray scale to extract the refined transmission map with the help of fast bilateral filter. Jiao Long et al. (2012) [14] has introduced a basic however successful technique to uproot haze or fog from a solitary remote sensing picture. This technique is depends upon the dark channel prior and a normal cloudiness-imaging model. Remote sensing pictures are broadly utilized within different fields. Kaiming He et al. (2011) [15] has concluded that the dark channel prior is a sort of statistics of outdoor haze-free images. It is dependent upon a key perception that the most nearby patches in outdoor haze-free images encompass some pixels whose strength is very low in at least one color channel. Jing et al (2010) [13] explained that imaging in poor weather is often degraded by scattering due to hanging particles in the atmosphere such as haze, fog and mist. They proposed a novel fast defogging method from a single image of a scene based on a fast bilateral filtering technique. The complexity of this method is only a linear function of the number of input image pixels and thus allows a very fast performance. Implementations on a variety of outdoor foggy images demonstrate that method achieves good restoration for contrast and color fidelity, resulting in a large improvement in image visibility.Chao-Tsung Chu and Ming-Sui Lee (2010) [14] has proposed a content adaptive technique for single image dehazing. Since the degradation level damaged by haze is connected to the depth of the scene and pixels in each specific part of the image (such as trees, buildings or other objects) tend to have similar depth to the camera. Chao-Tsung Chu and Ming-Sui Lee assumed that the degradation level affected by haze of each region is the same such that the transmission in each region should be similar as well. Based on these situations, each input image is divided into different regions and transmission is estimated for each region followed by modification by soft matting and the hazy images can be successfully recovered. Guo Fan et al (2010) [15] developed a simple but effective method for visibility restoration from a single image. The main benefit of the planned method is no user interaction is needed, this allows our algorithm to be applied for practical applications, such as surveillance, intelligent vehicle, etc. Another advantage is its speed, since the cost of obtaining transmission map is really cut down by using Retinex technique on luminance component. Jing et al (2010) [16] discussed that imaging in poor weather is often harshly degraded by scattering due to floating particles in the atmosphere such as haze, fog and mist. Poor perceptibility becomes main problem for most outdoor vision applications. Jing et al proposed a novel fast defogging technique from a single image of a scene based on a fast bilateral filtering method. The difficulty of this method is only a linear function of the number of input image pixels and this thus allows a very fast implementation. Nishino et al (2010) [17] studied that atmospheric conditions induced by suspended particles, such as fog and haze, severely alter the scene appearance. They introduce a novel Bayesian probabilistic method that jointly predicts the scene albedo and depth from a single foggy image by fully leveraging their latent statistical structures. The idea is to model the image with a factorial Markov random field in which the scene albedo and depth are two statistically independent latent layers and to jointly estimate them. Nishino et al showed that exploited natural image and depth statistics as priors on these hidden layers and estimate the scene albedo and depth with a canonical expectation maximization algorithm with alternating minimization.Yan Wang and Bo Wu (2010) [18] has studied that atmospheric conditions created by floating particles, such as fog and haze, cruelly degrade image quality. Haze removal from a single image of a weather-corrupted scene remains a challenging task, because the haze is based on the unknown depth information. In this paper, Yan Wang and Bo Wu introduced an improved single image de hazing method, which is based on the atmospheric scattering physics-based models. Yan Wang and Bo Wu applied the local dark channel prior on selected region to estimate the atmospheric light, and obtain more accurate result.ZhiyuanXu and Xiaoming Liu (2010) [19] has analyzed that the images affected by fog suffer from poor contrast. So to modify the contrast, a foggy image contrast enhancement method based on Bilinear Interpolation Dynamic Histogram Equalization has been proposed by ZhiyuanXu and Xiaoming Liu. First, the original foggy image is divided into same size sub-images. Then the histogram of each sub-image is divided into sub-histograms without command and then new active values are allocated for all such sub-histograms. Finally, HE and Bilinear Interpolation methods are applied to the image respectively. Experimental results show that the proposed method gave better quality of image.

[3] PROPOSED ALGORITHM

Fog removal likewise recognized as visibility restoration refers to diverse techniques that intend to diminish or uproot the degradation that have happened while the digital image was being acquired. The degradation may be because of different reasons alike relative object-camera movement, distortion because of camera miss-focus, relative atmospheric turbulence and others. This research work will be concentrated around the degradations because of awful climate, for example, mist, fog, rain and snow in an picture. The picture quality of outside screen in the haze and foggy climate condition is usually degraded by the distribution of a light before arriving the camera because of these huge amounts of suspended particles (e.g. haze, fog, smoke, contaminations) in the air.This occurrencedisturbs the usual work of automatic monitoring system, outdoor recognition system and intelligent transportation system.Scattering is brought on by two major phenomena, for example, attentuation and air light. By the use of viable haze evacuation of picture one can enhance the stability and power of the visual system. Haze removal has discovered to be an intense task in light of the fact that fog relies on the unknown scene depth information. Fog effect is the function of distance between camera and object. Thus evacuation of fog requires the estimation of air light map. The current haze evacuation technique could be isolated into two classes: picture enhancement and picture restoration. Picture upgrade does exclude the reasons of haze degrading picture quality. This technique can enhance the contrast of haze picture however loses a portion of the data in regards to picture. Picture restoration firstly examines the physical methodology of picture imaging in foggy climate. After observing that degradation a model of fog image will be recognized . Finally, the degradation procedure is modified to produce the haze free picture without the corruption. Thus, the quality of degraded image could be corrected.



This section contains the various steps required to remove the fog from the input image. The figureabove shows the flow chart of the proposed algorithm.

Step 1: Read the Input image
Step 2: Apply Gabor filter to reduce the noise from the image.
Step 3: Apply proposed algorithm
a. Apply dark channel prior
b. Apply CLAHE on R,G and B separately
c. Now histogram stretching will come in action to improve accuracy.
Step 4: Final image which has been visibly restored.

[4] EXPERIMENTAL SET-UP

In order to implement the proposed algorithm; design and implementation has been done in MATLAB using image processing toolbox. In order to do cross validation we have also implement the histogram equalization and nonlinear enhancement technique. Table 1 is showing the various images which are used in this research work. Images are given along with their formats. All the images are of different kind and each image has different kind of the light i.e. more or less in some images.

Table 1. Experimental images

Sr.No.	NAME	FORMAT
1	image1	JPG
2	image2	JPG
3	image3	JPG
4	image4	JPG
5	image5	JPG
6	image6	JPG
7	image7	JPG
8	image8	JPG
9	image9	JPG
10	image10	JPG
11	image11	JPG
12	image12	JPG
13	image13	JPG
14	image14	JPG
15	image15	JPG
16	image16	JPG

[5] EXPERIMENTAL RESULTS

For the purpose of cross validation we have taken 16 different images and passed to the dark channel prior and proposed algorithm. Subsequent section contains a result of one of the 15 selected images to show the improvisation of the proposed algorithm over the other techniques.

Figure 3: Input image

Figure 3 has shown the input image for experimental purpose. The image has low brightness and seems to be effected by the fog a lot. The overall objective is to improve the visibility of the image and also reduce the effect of the fog.

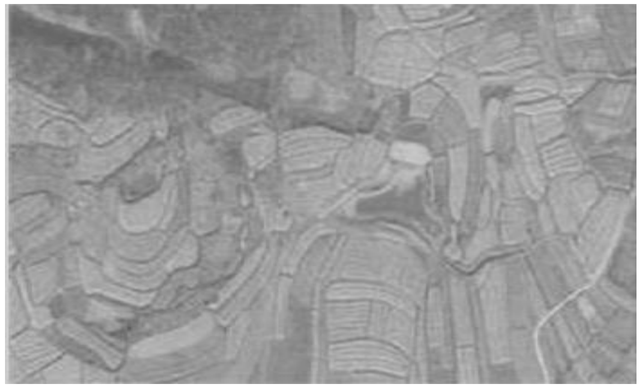


Figure 4: dark channel prior output

Figure 4 has shown the output image taken by the channel prior. The image has contained too much brightness and some more artifacts. However this algorithm has efficiently removed the fog form the image shown in figure 4. But the problem of this technique is found to be some artifacts which have degrades the quality of the image. Also the image has shown very darker results.

Figure 5: Proposed technique

Figure 5 has shown the output image taken by the integrated technique of fog removal. The image has contained the balanced brightness and the artifacts have also been reduced. Comparing with other method the proposed has shown quite significant result with respect to all cases. The effect of the individual channel has also been normalized as well as the effect of the brightness is also normalized.

[6] PERFORMANCE ANALYSIS

This section contains the cross validation between existing and proposed techniques. Some well-known image performance parameters for digital images have been selected to prove that the performance of the proposed algorithm is quite better than the available methods.

Table 2 has shown the quantized analysis of the mean square error. As mean square error need to be reduced therefore the proposed algorithm is showing the better results than the available methods as mean square error is less in every case.

Table 2. Mean Square Error

Image Name	Proposed Algorithm	Old Technique
Img1	0.1233	0.1752
Img2	0.1406	0.2291
Img3	0.1425	0.2043
Img4	0.1459	0.1784
Img5	0.1158	0.2027
Img6	0.1132	0.3008
Img7	0.1168	0.2419
Img8	0.1539	0.1915
Img9	0.1487	0.3421
Img10	0.0906	0.1407
Img11	0.1605	0.1820
Img12	0.1272	0.1443
Img13	0.1702	0.2013
Img14	0.1552	0.2089
Img15	0.1467	0.1516
Img16	0.1080	0.2728

Table 3 is showing the comparative analysis of the Peak Signal to Noise Ratio (PSNR). As PSNR need to be maximized; so the main goal is to increase the PSNR as much as possible. Table 3 has clearly shown that the PSNR is maximum in the case of the proposed algorithm therefore proposed algorithm is providing better results than the available methods.

Table 3. Peak Signal -to- Noise Ratio

Image Name	Old Technique	Proposed Algorithm
Img1	63.2585	66.3095
Img2	60.9294	65.1692
Img3	61.9249	65.0515
Img4	63.1048	64.8516
Img5	61.9946	66.8574
Img6	58.5657	67.0568
Img7	60.4597	66.7801
Img8	62.4861	64.3854
Img9	57.4478	64.6828
Img10	65.1645	68.9906
Img11	62.9298	64.0189
Img12	64.9469	66.0409
Img13	62.0555	63.5100
Img14	61.7302	64.3120
Img15	64.5186	64.8006
Img16	59.4135	67.4638

Table 4 has shown the median angular error between existing and the proposed technique. It has been clearly shown that the median angular error is low in the case of the proposed technique. Therefore the proposed technique has shown significant results.

Table 4. Median Angular Error

Image Name	Old Technique	Proposed Algorithm
Img1	8.7617	6.1664
Img2	11.9562	7.0315
Img3	10.2157	7.1275
Img4	8.9180	7.2934
Img5	10.1340	5.7895
Img6	15.0392	5.6581
Img7	12.0928	5.8412
Img8	9.5765	7.6956
Img9	17.1050	7.4365
Img10	7.0354	4.5287
Img11	9.0996	8.0272
Img12	7.2138	6.3601
Img13	10.0631	8.5115
Img14	10.4472	7.7608
Img15	7.5785	7.3363
Img16	13.6407	5.3991

Table 5 has shown the Mean Difference between existing and the proposed technique. It has been clearly shown that the Mean Difference is low in the case of the proposed technique. Therefore the proposed technique has shown significant results.

Table 5. Mean Difference analysis

Image Name	Old Technique	Proposed Algorithm
Img1	0.0307	0.0152
Img2	0.0525	0.0198
Img3	0.0417	0.0203
Img4	0.0318	0.0213
Img5	0.0411	0.0134
Img6	0.0905	0.0128
Img7	0.0585	0.0136
Img8	0.0367	0.0237
Img9	0.1170	0.0221
Img10	0.0198	0.0082
Img11	0.0331	0.0258
Img12	0.0208	0.0162
Img13	0.0405	0.0290
Img14	0.0437	0.0241
Img15	0.0230	0.0215
Img16	0.0744	0.0117

Figure 6 has shown the quantized analysis of the mean square error. As mean square error need to be reduced therefore the proposed algorithm is showing the better results than the available methods as mean square error is less in every case.

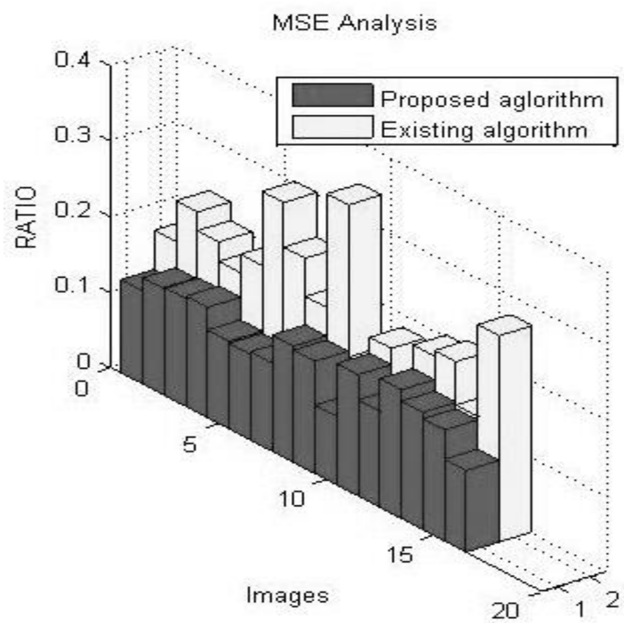


Figure 6.Mean Square Error

Figure 7 is showing the comparative analysis of the Peak Signal to Noise Ratio (PSNR). As PSNR need to be maximized; so the main goal is to increase the PSNR as much as possible. Figure 10 has clearly shown that the PSNR is maximum in the case of the proposed algorithm therefore proposed algorithm is providing better results than the available methods.

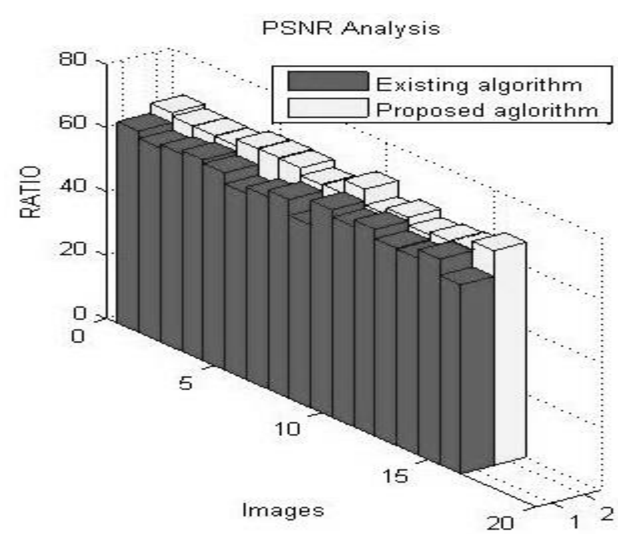


Figure 7.Peak Signal –to- Noise Ratio

Figure 8 has shown the comparison among the existing and proposed fog removal technique based upon the medina angular error. The comparative analysis has clearly shown that the proposed technique has quite better results than the available techniques.

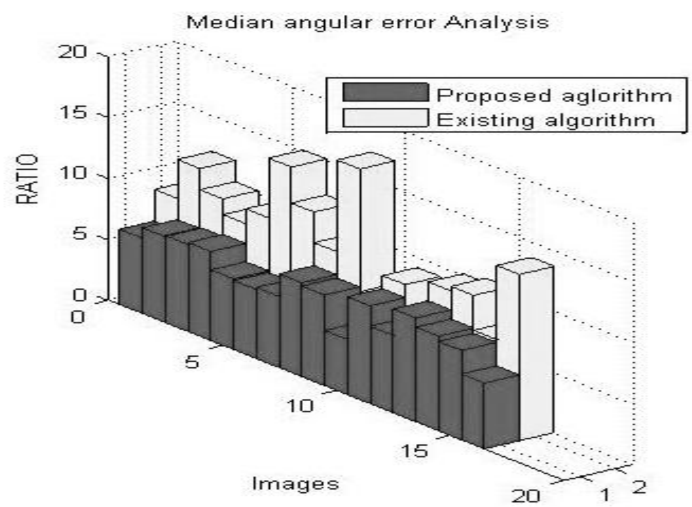


Figure 8. Median Angular Error

Figure 9 has shown the comparison among the existing and proposed fog removal technique based upon the mean difference. The comparative analysis has clearly shown that the proposed technique has quite better results than the available techniques with respect to mean difference analysis.

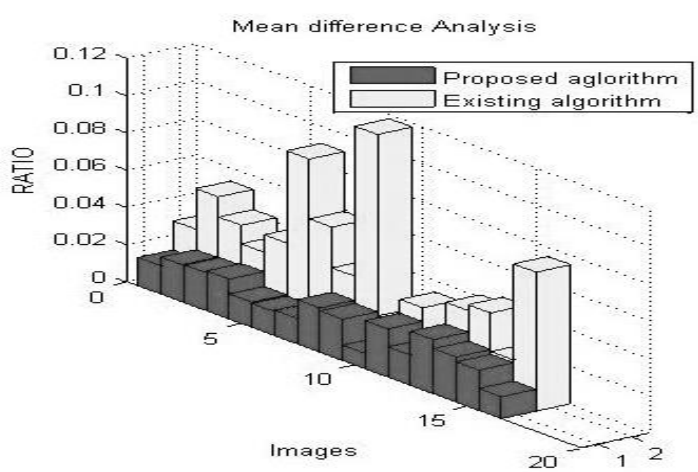


Figure 9 Mean difference analysis

[7] CONCLUSION AND FUTURE WORK

Fog evacuation algorithms have wound up more profitable for some vision applications. It is found that most of the current researchers have ignored various issues; i.e. no strategy is right for unique kind of circumstances. The current frameworks have rejected the usage of histogram stretching and Gabor filter to reduce the noise issue, which will be shown in the yield picture of the current fog evacuation algorithms. To beat the issues of existing research another coordinated algorithm has been proposed. New algorithm has coordinated the dark channel prior, CLAHE and histogram stretching to enhance the results. The Gabor filtering is done as a preprocessing step to vanish the noise from the input image. The blueprint and use of the proposed algorithm has been done in MATLAB using image processing toolbox. The association has showed that the proposed calculation beats over the existing calculations. In not so distant future we will change this method further to use fuzzy based picture improvement methodology to enhance the results further.

REFERENCES

[1] Tarel, J-P., and Nicolas Hautiere. "Fast visibility restoration from a single color or gray level image." Computer Vision, 2009 IEEE 12th International Conference on.IEEE, 2009.

[2] Xu, Haoran, et al. "Fast image dehazing using improved dark channel prior." Information Science and Technology (ICIST), 2012 International Conference on. IEEE, 2012.

[3] Xu, Zhiyuan, Xiaoming Liu, and Na Ji. "Fog removal from color images using contrast limited adaptive histogram equalization." Image and Signal Processing, 2009.CISP'09.2nd International Congress on.IEEE, 2009.

[4] Shuai, Yanjuan, Rui Liu, and Wenzhang He. "Image Haze Removal of Wiener Filtering Based on Dark Channel Prior." Computational Intelligence and Security (CIS), 2012 Eighth International Conference on. IEEE, 2012.

[5] Tripathi, A. K., and S. Mukhopadhyay. "Single image fog removal using bilateral filter." Signal Processing, Computing and Control (ISPCC), 2012 IEEE International Conference on. IEEE, 2012.

[6] Kil, Tae Ho, Sang Hwa Lee, and Nam Ik Cho. "A dehazing algorithm using dark channel prior and contrast enhancement." Acoustics, Speech and Signal Processing (ICASSP), 2013 IEEE International Conference on.IEEE, 2013.

[7] Ullah, E., R. Nawaz, and J. Iqbal. "Single image haze removal using improved dark channel prior." Modelling, Identification & Control (ICMIC), 2013 Proceedings of International Conference on. IEEE, 2013.

[8] Hitam, M. S., et al. "Mixture contrast limited adaptive histogram equalization for underwater image enhancement." Computer Applications Technology (ICCAT), 2013 International Conference on.IEEE, 2013.

[9] Cheng, F-C., C-H. Lin, and J-L. Lin. "Constant time O (1) image fog removal using lowest level channel." Electronics Letters 48.22 (2012): 1404-1406.

[10] Tripathi, A. K. and S. Mukhopadhyay. "Single image fog removal using anisotropic diffusion." Image Processing, IET 6, no. 7 (2012): 966-975.

[11] Long, Jiao, Zhenwei Shi, and Wei Tang. "Fast haze removal for a single remote sensing image using dark channel prior." Computer Vision in Remote Sensing (CVRS), 2012 International Conference on.IEEE, 2012.

[12] He, Kaiming, Jian Sun, and Xiaoou Tang. "Single image haze removal using dark channel prior." Pattern Analysis and Machine Intelligence, IEEE Transactions on 33.12 (2011): 2341-2353.

[13] Yu, Jing, Chuangbai Xiao, and Dapeng Li. "Physics-based fast single image fog removal." Signal Processing (ICSP), 2010 IEEE 10th International Conference on.IEEE, 2010.

[14] Chu, Chao-Tsung, and Ming-Sui Lee. "A content-adaptive method for single image dehazing." Proceedings of the Advances in multimedia information processing and 11th Pacific Rim conference on Multimedia: Part II. Springer-Verlag, 2010.

[15] Guo, Fan, CaiZixing, Xie Bin and Tang Zin . "Automatic Image Haze Removal Based on Luminance Component." Wireless Communications Networking and Mobile Computing (WiCOM), 2010 6th International Conference on. IEEE, 2010.

[16] Yu, Jing, Chuangbai Xiao, and Dapeng Li "Physics-based fast single image fog removal." Signal Processing (ICSP), 2010 IEEE 10th International Conference on.IEEE, 2010.

[17] Nishino, Ko, Louis Kratz, and Stephen Lombardi. "Bayesian defogging."International journal of computer vision 98.3 (2012): 263-278.

[18] Wang, Yan, and Bo Wu. "Improved single image dehazing using dark channel prior." Intelligent Computing and Intelligent Systems (ICIS), 2010 IEEE International Conference on. Vol. 2. IEEE, 2010.

[19] Xu, Zhiyuan, and Xiaoming Liu. "Bilinear interpolation dynamic histogram equalization for fog-degraded image enhancement." J InfComputSci 7.8 (2010): 1727-1732.