International Journal of Hybrid Information Technology
Vol.7, No.4 (2014), pp.235-248
http://dx.doi.org/10.14257/ijhit.2014.7.4.20

A Novel Defogging Technique for Dehazing Images

Atul Gujral[1], Shailender Gupta[2] and Bharat Bhushan[3]

[1,2] YMCA University of Science and Technology
Sector-6 Faridabad-121006
[1]atul.gujral5@gmail.com, [2]shailender81@gmail.com, [3]bhrts@gmail.com

Abstract

Fog is a combination of two components airlight and direct attenuation, degrades the picture quality and creates a lot of problem in video surveillance, tracking and navigation. Thus, to remove it from an image, various defogging methods have been proposed in literature. Defogging can achieved using multiple images and single image fog removal method. One of the prominent methods in literature for defogging is Dark Channel Prior (DCP). This method though quite effective in removing fog from images has very high time complexity. In addition, it does not preserve edges and has halo effect. Therefore, this paper proposes a new technique which overcomes the disadvantage of DCP and at the same time preserves the picture quality. The proposed method is implemented in MATLAB-09 and the simulation results show the proposed method is quite good.

Keywords: *Single image dehazing, Dark channel, Atmospheric light and Transmission map*

1. Introduction

Poor visibility not only reduces perceptual picture quality but also deteriorates the performance of the computer vision algorithms such as surveillance, tracking and navigation. Optically, poor visibility in unclear weather is due to the substantial presence of water droplets. These droplets have significant size (1-10 μm) and distribution in the participating medium. Atmospheric light and reflected light from an object are scattered by these droplets, resulting in poor picture quality. Thus we can say that fog is an addition of air-light and attenuation to an image represented by equation (1):

$$\text{Fog} = \text{Direct Attenuation} + \text{Air-light} \tag{1}$$

In the above equation, attenuation is the gradual loss in intensity of any kind of flux through a medium. Mathematically it can be expressed by equation (2) as:

$$\text{Direct Attenuation} = J(x).t(x) \tag{2}$$

Where J(x) is the Scene Radiance and t(x) is the Medium Transmission. The Direct Attenuation describes the scene radiance and its decay in the medium; it is a multiplicative distortion of the scene radiance. When the atmosphere is homogenous, the transmission t(x) can be expressed in equation (3) as:

$$t(x) = e^{-\beta d(x)} \tag{3}$$

Where β is the scattering coefficient of the atmosphere and d is the scene depth of the x^{th} pixel. The equation (3) indicates that the scene radiance is attenuated exponentially

ISSN: 1738-9968 IJHIT

with the depth. If the transmission map can be recovered then depth map can be recovered to an unknown scale. Figure 1 (a) and Figure 1(b) show the natural image and the impact of attenuation on it.

Figrue 1. (a) Natural Image

Figure 1.(b) Effect of Attenuation

Air-light is caused due to scattering of light. It adds whiteness to the scene. It is additive in nature and is a function of the distance between camera and object. Mathematically the equation of air-light can be described as below (refer equation 4).

$$\text{Air-light} = A\,(1-e^{-\beta d(x)}) \quad (4)$$

Where, A is global atmospheric light.

Using equation (1)-(4) the intensity value (I) of xth pixel of a foggy image can be defined as [1-4], (see equation 5):

$$I(x) = J(x).t(x) + A\,(1-t(x)) \quad (5)$$

Figure 2. (a) Natural Foggy Image

Figure 2. (b) Effect of Air Light

The effect of airlight is shown in Fig. 2(b) for the natural foggy image.

Thus it is clear from the above images that fog deteriorates image quality and the main cause of it is air-light and attenuation. Therefore, removal of fog requires knowledge of transmission map and airlight map. In this paper a new method of removing fog has been proposed. The rest of the paper is structured as follows: Section 2 has literature survey and problem definition, Section 3 has proposed model, Section 4 has simulation setup parameters, Section5 has result and then followed by conclusion and references.

2. Literature Survey and Problem Definition

2.1. Literature Survey

Defogging can be done by two ways *i.e.*, multiple images fog removal method and single image fog removal method. Multiple images fog removal techniques includes various methods described below:

Vision in bad weather [5] was proposed by S. K. Nayar *et. al*. In this method multiple images under different weather conditions of the same scene are taken and are then combined to remove fog from image.

Later the concept of polarization filters [6-7] was used. These methods used different degree of polarization to remove haze from images.

The above methods have the following drawbacks:

- Multiple images are required to remove fog from image.
- Time complexity of the process is too high.

Thus, single image fog removal methods were proposed, that has much lower time complexity then multiple image fog removal techniques. These methods are as follows:

2.1.1. Dark Channel Prior Technique (DCP): This method [10] estimates transmission map [4], [9] and air-light to recover original one from foggy image. To estimates the transmission map [11], it uses the lowest intensity pixel of image in 3 color planes in patch size of different variations, after which soft matting [8] and bilateral filter [15] operation are performed to get final defogged image. Block diagram for DCP algorithm is shown in Figure 3.

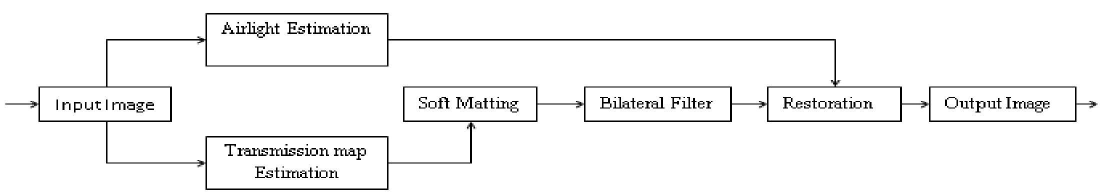


Figure 3. Block Diagram of DCP Algorithm

This method may not be efficient at times as it may corrupt the image when it contains multiple large lamps since the estimation of atmospheric light is automatic.

2.1.2. Improved Single Image Dehazing using Dark Channel Prior: In this proposal [12], a novel estimation of atmospheric light has been proposed. Compared to the Dark Channel Prior method, it can obtain better results and also resolves that the substantial sky region of recovered image usually tends to be distorted. Block diagram of this method is shown in Figure 4.

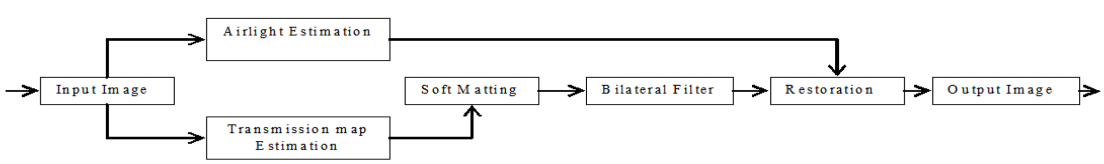


Figure 4. Block Diagram of IDCP Algorithm

IDCP has same procedure as DCP, the method gets modify in estimation of atmospheric light and image recovered method which is described below.

2.1.2.1. Atmospheric Light Estimation: The window size has increased to 31; the atmospheric light will be properly estimated amongst the pixels having thick haze.

2.1.2.2 Image Restoration: In this step, image is restored. The value of restored image is given in equation (6) as:

$$J(x) = \frac{I(x) - A}{\max(t(x), t_0)} + A \quad (6)$$

Where J is restored image pixel values. A typical value of t_0 is 0.35. t_0 is 0.1; it needs to be increased, when an image contains substantial sky regions, to avoid artefacts. With t_0 as 0.35, the sky region becomes brighter and smoother.

2.1.3. Improved Haze Removal Algorithm using Dark Channel Prior (based on Guided Filter): Dark Channel Prior may not work on particular images, especially where the large grey region is similar to the global atmospheric light. In this approach [13], atmospheric light is estimated, based on the imaging law of very dense hazy regions more accurately. Also, a replacement mechanism is designed for optimizing the rough transmission map, it wouldn't process on that area where it don't require which is shown in Figure 5.

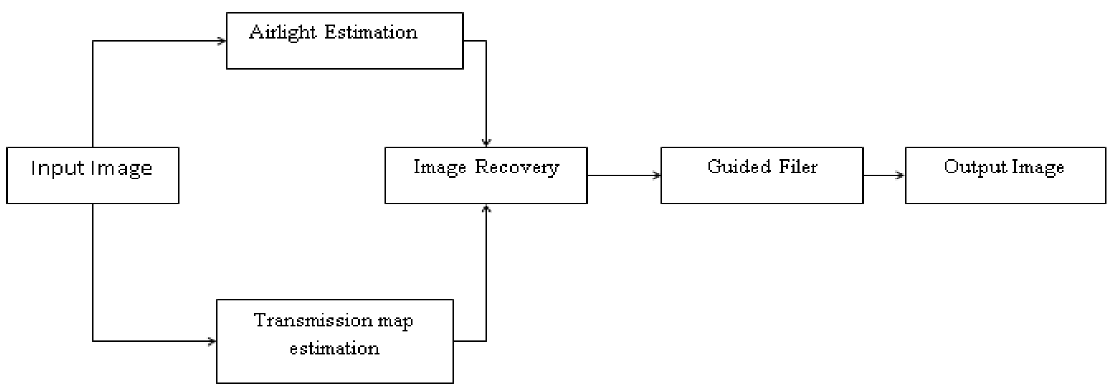


Figure 5. Block Diagram of IDCP Algorithm using GUIDED FILTER

2.1.4. An Improved Single Image Haze Removal Algorithm Based on Dark Channel Prior and Histogram Specification: Improved DCP with histogram specification [14] has been proposed to improve the contrast of the recovered image which involves rebuilding the histogram of image with following advantages.

1. Firstly, prevents reduction of the image contrast.
2. Secondly, DCP method don't underestimates the attenuation of the foreground irradiance though haze.
3. Thirdly, if the haze image has large background area or low contrast then also it prevents from merges the scene with the thick haze.

Due to the above advantages, Improved DCP with histogram specification has been proposed to improve the contrast of the recovered image which involves rebuilding the histogram of image.

Disadvantage:
If the haze in the image is not removed clearly, this method will increase the thickness of the haze.

2.2. Problem Definition

Before discussing the problem we would like to give a brief introduction about the parameters such as time complexity, halo effect and edge preservation that will enable user for its better understanding.

2.2.1. Halo Effect: A halo (also known as a nimbus, icebow or gloriole) is an optical phenomenon produced by ice crystals creating coloured or white arcs and spots in the sky. Many are near the sun or moon but others are elsewhere and even in the opposite part of the sky. They can also form around artificial lights in very cold weather when ice crystals called diamond dust are floating in the nearby air. Figure 6 shows the pictorial representation of halo effect.

Figure 6. White Circle Around Sun shows Halo Effect

2.2.2. Edge Preservation: The corner pixel values in image get distorted in various methods while restoring of image which is reduced in our proposed method.

2.2.3. Time Complexity: The time taken by the technique to remove fog from image.

By implemented all DCP techniques discussed above, time complexity and halo effect has been analyzed and compares as shown in Table 1:

Table 1. Comparison of DCP Technique with its Advanced Version Techniques

Parameter	DCP	Improved DCP	Guided Filter	Histogram Specification
TIME	VERY HIGH	HIGH	LOW	LOW
HALO EFFECT	VERY HIGH	MEDIUM	LOW	HIGH

It is quite clear from the above table that DCP and its advance version techniques suffer from halo and edge deterioration effect. In addition has very high time complexity. Thus, there is a need for a new technique that preserves picture quality and optimises the above mentioned parameters. The next section gives the proposed technique.

3. Proposed Method

3.1. Introduction

The method presented in [10] shows DCP defogging algorithm that uses RGB color model. Zere the new defogging algorithm has been proposed with modified transmission map. Figure 4 shows the block diagram of proposed model. The foggy image equation used in this paper is as follows:

$$f^c(x,y) = f^c_d(x,y)t(x,y) + A(1-t(x,y)), \quad \text{for c } \{R, G, B\} \tag{7}$$

where first term in RHS of equation (7) is direct attenuation and second term is airlight of a particular pixel. It also involves estimation of air-light map and transmission map to refine the foggy image.

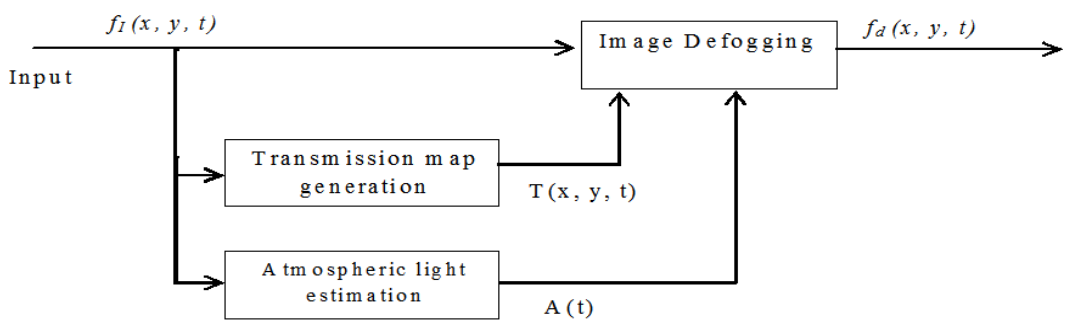


Figure 7. Block Diagram of Proposed Method

3.2. Transmission Map Estimation

Here the modified transmission map is as follows:

1. Create a map having minimum pixel values of the three colour planes. It is denoted by TM and is expressed in equation (8):

$$TM(x,y) = \min_{c \in r,g,b} f_I(x,y,c) \tag{8}$$

2. Separate the different objects in TM
3. Take minimum intensity pixel value called as test of the differentiated object. It should be noted that edges remain unaltered but the pixel values inside object values are modified as shown in equation (9):

$$T_0(x,y) = a * test - t_d(x,y) \tag{9}$$

Where the value of 'a' is taken to be 2.34 after optimization and $t_d(x, y)$ is the intensity value differentiated object.

4. Combine all the objects and is denoted by 'T'.

3.3. Atmospheric Light Estimation

We pick the top 0.1 percent brightest pixels from the transmission map as given by Tan *et. al.*, [4].

3.1.4. Image Restoration

Given the atmospheric light A and the modified transmission map T(x, y), RGB components of the defogged image frame can be recovered from equation (10):

$$f_d(x, y, c) = \frac{(f(x,y,c) - A(t))}{(t0 - T(x,y,c))} + A \quad (10)$$

where c is frame number
t_o is parameter for removing artefacts.

4. Simulation Setup Parameters and Tool Used

Table 2. Simulation Setup Parameters

SETUP PARAMETERS	SPECIFICATION
SOFTWARE USED	MATLAB 2009
SYSTEM RAM	3 G.B.
SYSTEM PROCESSOR	Intel(R)Core(TM) i3
CPU	M350 @ 2.27GHz

Fog is artificially created in above experiments.

Various simulation setup parameters used for different methods discussed above are given in Table 3-6.

Table 3. DCP Algorithm Parameters

Ꞷ (Constant Parameter)	0.95
D (scene depth)	1.5
β (atmospheric scattering coefficient)	0.5
t_0 (minimum transmission limit)	0.1
Patch size used	15*15

Table 4. IDCP Algorithm Parameters

D (scene depth)	1.5
β (atmospheric scattering coefficient)	0.5
t_0 (minimum transmission limit)	0.35
Patch size used	31*31

Table 5. IDCP using Guided Filter Algorithm Parameters

α (Constant Parameter)	2
Ꞷ (Constant Parameter)	0.95
D (scene depth)	1.5
β (atmospheric scattering coefficient)	0.5
t_0 (minimum transmission limit)	0.35
Patch size used	15*15

Table 6. Histogram Specification Algorithm Parameters

ω (Constant Parameter)	0.95
D (scene depth)	1.5
β (atmospheric scattering coefficient)	0.5
t_0 (minimum transmission limit)	0.1
Patch size used	15*15

Table 7. Modified Transmission Map with DCP Specification Algorithm Parameters

D (scene depth)	1.5
β (atmospheric scattering coefficient)	0.5
t_0 (minimum transmission limit)	1.76
a(optimization parameter)	2.34

5. Results

Figure 8 shows the pictorial quality of the image obtained after recovery. Following inference can be drawn after careful analysis

• The pic quality of the proposed mechanism is nearly same as that of DCP and its derivatives.

• The halo effect and edge preservation are achieved in our proposal.

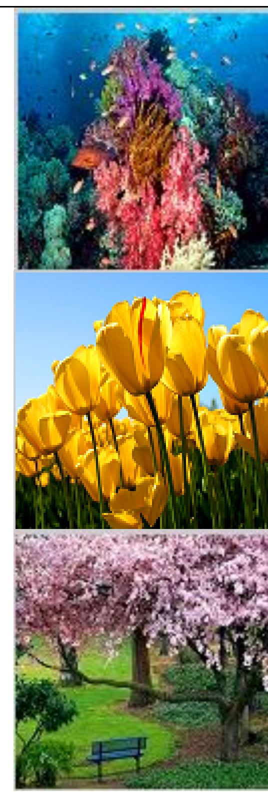
Method	Foggy Image	Defoggy Image
DCP		

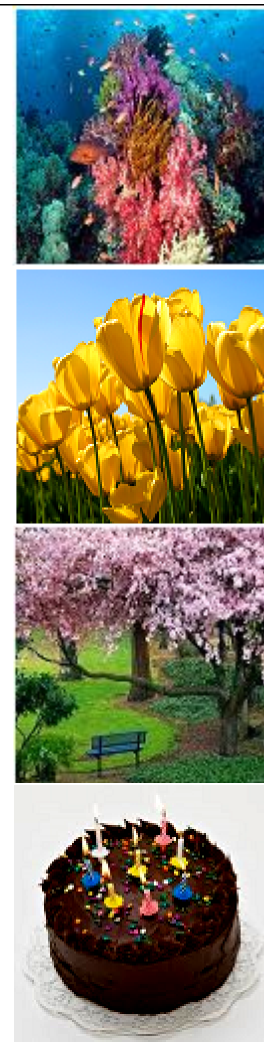
	 Figure 8. (a) Original Image	 Figure 8. (b) Recovered Image
IDCP		

	 Figure 8. (c) Original Image	 Figure 8. (d) Recovered Image
IDCP with the guided filter	 Figure 8. (e) Original Image	 Figure 8. (f) Recovered Image

IDCP with the Histogram Specification	 Figure 8. (g) Original Image	 Figure 8. (h) Recovered Image

Modified Transmission Map DCP	 Figure 8. (i) Original Image	 Figure 8. (j) Restored Image

Figure 8. Snapshots of Various Results Obtained

Figure 9 shows the impact on time complexity of various defogging algorithms as discussed above. The following inferences can be drawn from the results:

• As the size increases the time complexity of all the DCP techniques and proposed ones increases

• The time complexity of the proposed strategy is quite low since all the DCP techniques uses Laplacian operators.

• With increase in image size, the time complexity gets increases but for Modified DCP method it still lowers as compare to other DCP methods as shown in Figure 9.

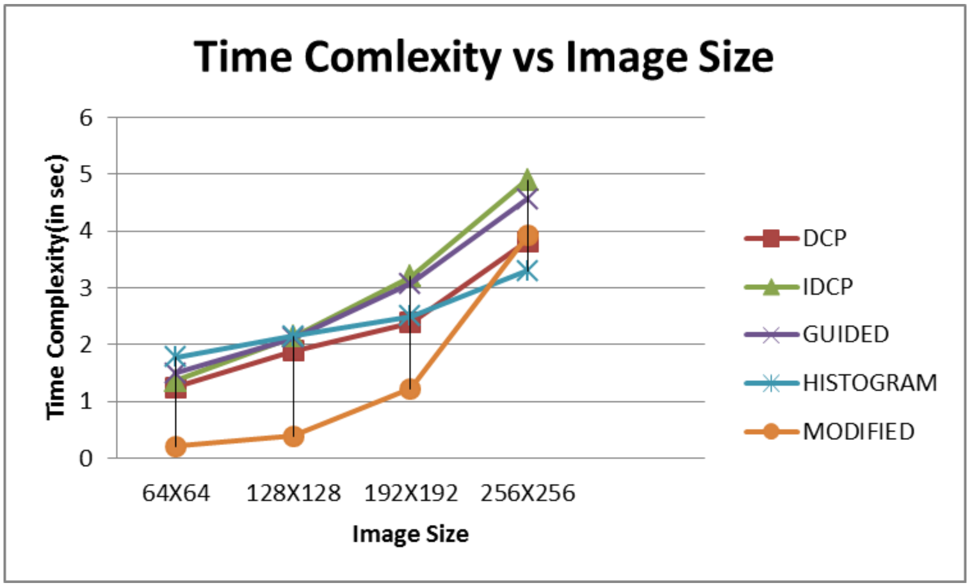


Figure 9. Time Complexity v/s Size of an Image

6. Overall Inference

Table 8. Comparison of various Algorithms in Terms of Performance Metrics

Parameter	DCP	Improved DCP	Guided Filter	Histogram Specification	Modified
TIME	VERY HIGH	HIGH	LOW	LOW	VERY LOW
HALO EFFECT	VERY HIGH	MEDIUM	LOW	HIGH	VERY LOW
EDGE PRESERVATION	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH

This paper is an effort to propose a new defogging algorithm. Following important inferences can be made on the basis of the results shown in Table 8:-

• In terms of time complexity; proposed method is the best.
• Halo effects have been removed very significantly.
• Edges get preserved by the proposed method.

The proposed model can be quite helpful for researchers, working in this direction.

References

[1] S. G. Narasimhan and S. K. Nayar, "Vision and the Atmosphere", International Journal on Computer Vision, vol. 48, **(2002)**, pp. 233-254.
[2] S. G. Narasimhan and S. K. Nayar, "Chromatic Framework for Vision in Bad Weather", Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, vol. 1, **(2000)** June, pp. 598-605.
[3] R. Fattal, "Single Image Dehazing", proceedings of ACM SIGGRAPH, **(2008)**, pp. 1-9.

[4] R. Tan, "Visibility in Bad Weather from a Single Image", proceedings of IEEE Conference on Computer Vision and Pattern Recognition, **(2008)** June, pp. 1-8.
[5] S. K. Nayar and S. G. Narashiman, "Vision in bad weather", Proc. Seventh IEEE Int'l Conf. Computer Vision, vol. 2, **(1999)**, pp. 820-827.
[6] Y. Y. Schechner, S. G. Narasimahan and S. Nayar, "Polarization-based vision through haze", Applied Optics, vol. 42, no. 3, **(2003)**, pp. 511-525.
[7] S. Shwartz, E. Namer and Y. Schechner, "Blind haze separation", Proc. IEEE Int. Conf. Computer Vision, Pattern Recognition, **(2006)** October, pp. 1984-1991.
[8] A. Levin, D. Lischinski and Y. Weiss, "A Closed Form Solution to Natural Image Matting", Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, vol. 1, **(2006)**, pp. 61-68.
[9] R. Fattal, "Single imaze dehazing", ACM Transactions on Graphics, vol. 27, no. 3, **(2008)** August, pp. 1-9.
[10] K. He, J. Sun and X. Tang, "Single image haze removal using dark channel prior", IEEE Int. Conf. On Computer Vision and Pattern Recognition, **(2009)**, pp. 1956-1963.
[11] J. Oakley and B. Satherley, "Improving image quality in poor visibility conditions using a physical model for constant degradation", IEEE Transactions on Image Processing, vol. 7, no. 2, **(1998)**, pp. 167-169.
[12] Y. Wang and B. Wu, "Improved Single Image Dehazing using Dark Channel Prior", Proc. IEEE Conf. Intelligent Computing and Intelligent Systems (ICIS), vol. 2, **(2010)**, pp. 789-792.
[13] Y. Xiong and H. Yan, "Improved Single Image Dehazing using Dark Channel Prior", Journal of Computational Information Systems, vol. 9, **(2013)**, pp. 5743-5750.
[14] S. Yang, Q. Zhu, J. Wang, D. Wu and Y. Xie, "An Improved Single Image Haze Removal Algorithm Based on Dark Channel Prior and Histogram Specification", Proceedings of 3rd International Conf. On Multimedia Technology, Atlantis Press, **(2013)**, pp. 279-292.
[15] C. Tomasi and R. Manduchi, "Bilateral Filtering for Gray and Color Images", Proceedings of Sixth IEEE International Conference on Computer Vision, **(1998)**, pp. 839-846.
[16] X. Jin and Z.-Y. Xu, "Speed-up single image dehazing using double dark channels", Proceedings of Fifth International Conference on Digital Image Processing (ICDIP), **(2013)**.
[17] S. Jeong and S. Lee, "The Single Image Dehazing based on Efficient Transmission Estimation", Proceedings of IEEE International Conference on Consumer Electronics (ICCE), **(2013)**, pp. 376-377.
[18] K. B. Gibson and V. Truong Q. Nguyen, "An investigation of Dehazing effects on image and Video Coding", IEEE Transactions on Image Processing, vol. 21, no. 2, **(2012)** February, pp. 662-673.
[19] J.-H. Kim, W.-D. Jang, J.-Y. Sim and C.-S. Kim, "Optimized contrast enhancement for real-time image and video dehazing", J. Vis. Commun. Image R., vol. 24, **(2013)**, pp. 410-425.
[20] S. Jeong and S. Lee, "The Single Image Dehazing based on Efficient Transmission Estimation", IEEE International Conference on Consumer Electronics (ICCE), **(2013)**, pp. 376-377.

Authors

Atul Gujral, received B.Tech. degree from the Career Institute of Technology and Management, Faridabad, India in 2012. He is currently working toward the M. Tech. degree form YMCAUST, Faridabad, India. His interests include digital signal processing.

Shailender Gupta, received B.Tech, M.Tech and Ph.D from YMCA University of Science and Technology, Faridabad, India. Currently he is working as Assistant Professor in Electronics Engineering Department in YMCAUST. His interests include digital signal processing and Mobile Ad hoc Network.

Bharat Bhushan, received B.Tech from Punjab Engineering College, Chandigarh, India and M.Tech from YMCA University of Science and Technology, Faridabad, India. Currently he is working as Assistant Professor in Electronics Engineering Department in YMCAUST. His interests include digital signal processing.

