Experimental Results and Analysis of Foggy Image by Single Image Dehazing Techniques

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ABSTRACT

Image de-fogging is the extreme significant in image processing. The problem generally arises due to hanging particles in the atmosphere. It causes a lot of scattering of light that gives rise to the blurring and noise creation in the image. Such conditions in image processing are really undesirable as it causes problem in object visibility and gives a whiteness undesirable effect in the image thus formed. This paper focuses on the review of many state of the art image de-fogging techniques and thus compares them with implementation in MATLAB 2016Ra image processing tool. In the first phase the image density has been calculated which shows the amount of haziness present in the image. In the second phase the image dehazing techniques has been employed. In the third phase, the results have been gathered in terms of the image quality metrics and analysis shows the comparative results of all the techniques. To clearly show the results the density of the output images is again computed that shows the effect of the technique employed on various images.

Keywords: image dehazing; depth map-based dark channel prior; polarization-based; image quality assessment.

INTRODUCTION

Image processing's main aim is to sharpen, visual, retrieve, restore, and identify an image. Haze (fog) or smog present in the air deform the image state of the outside scene. Haze present in an image is a brainstorming issue as it mulls the contrast and cause color distortion. It has been observed that if we take a picture in foggy or hazy weather conditions, the obtained image generally undergoes poor visibility. The far objects in the fog/haze lose the contrast in the image and get blurry with the surroundings. Previous works for haze removal/fog removal depend either on additional depth information or on multiple observations for the same scene. Representative works include (Srinivasa G. Narasimhan & Nayar, 2002), (Srinivasa G. Narasimhan & Nayar, 2003), (Shwartz, Namer, & Schechner, 2006), (Schechner, Narasimhan, & Nayar, 2001).

Schechner et al. (Schechner et al., 2001) noticed that the air-light scattered by atmospheric particles are partially polarized. So, they developed a quick method to reduce haze by taking two images taken through a polarizer at different angles. Narasimhan et al. proposed a scattering model which was physics-based (Srinivasa G. Narasimhan & Nayar, 2002), (Srinivasa G. Narasimhan & Nayar, 2003). Wherein, the scene details were recovered from two or more weather images. Single image defogging/ dehazing, in contrast with multiple images defogging/dehazing, is more challenging, since less information is available about the scene structure.

LITERARURE OVERVIEW

This section of the paper throws light on the way the image density can be calculated. The second part of this section elaborates on the major segments of the image dehazing techniques with complete reviews of the major contributions done by different researchers in that concern.

A. Calculation of Input image density

In this section, the density of the input image will be discussed. Bovik (Choi, You, & Bovik, 2015) has advised a reference-less perceptual fog density prediction model. It is based on fog aware statistical features and natural scene statistics (NSS). This model Fog Aware Density Evaluator (FADE) calculates visibility degree of a hazy/foggy image from a single image with no reference to an equivalent fog-free image, with no dependence on noticeable objects in an image, there was no training on human-rated judgments, with no side geographical camera information, with no estimate of depth-dependent transmission map. This method makes use of quantifiable deviations found in natural hazy/foggy and fog-free images for statistical regularities.

B. Image dehazing

Two chief groupings of methods of image de-hazing/defogging are as follows:

1) Methods that use multiple foggy images

The basic idea is to take multiple images of the same scene under the same weather conditions. This method obtained the known variables and avoid the unknown variables.

2) Methods that use Single foggy image

Single image defogging/dehazing methods can enhance hazy images captured under any state of the environment. Many methods/techniques had been proposed for improving the effectiveness of single image dehazing. Fattal (Fattal, 2008) offered a method to evaluate transmission and atmospheric light. (Fattal, 2008) used independent component analysis (ICA) to calculate the medium transmission and then improved the foggy images. This method used the statistics values to evaluate parameters for image restoration. So, the performance considerably depends on the input image. This approach failed when the fog is denser, and signal-to-noise ratio (SNR) is insufficient (Bansal, Singh Sidhu, & Jyoti, 2017).

C. Other Subjective Image Quality Criteria

Other than the above-said image quality measures some other subjective image quality metrics have also been evaluated here namely:

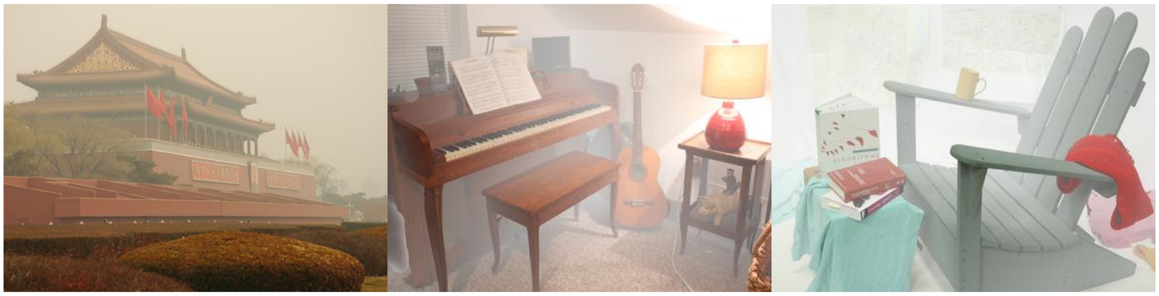
1. Mean Squared Error (MSE)
2. Normalized Absolute Error (NAE)

3. Normalized Cross Correlation (NK)
4. Maximum Difference (MD)
5. Peak Signal to Noise Ratio (PSNR)
6. Average Difference (AD)
7. Signal to Noise Ratio (SNR)

In the next section results of the Meng (Meng et al., 2013), Bovik (Choi et al., 2015), Cai (Cai et al., 2016) defogging algorithms along with their objective and subjective image quality metrics have been presented.

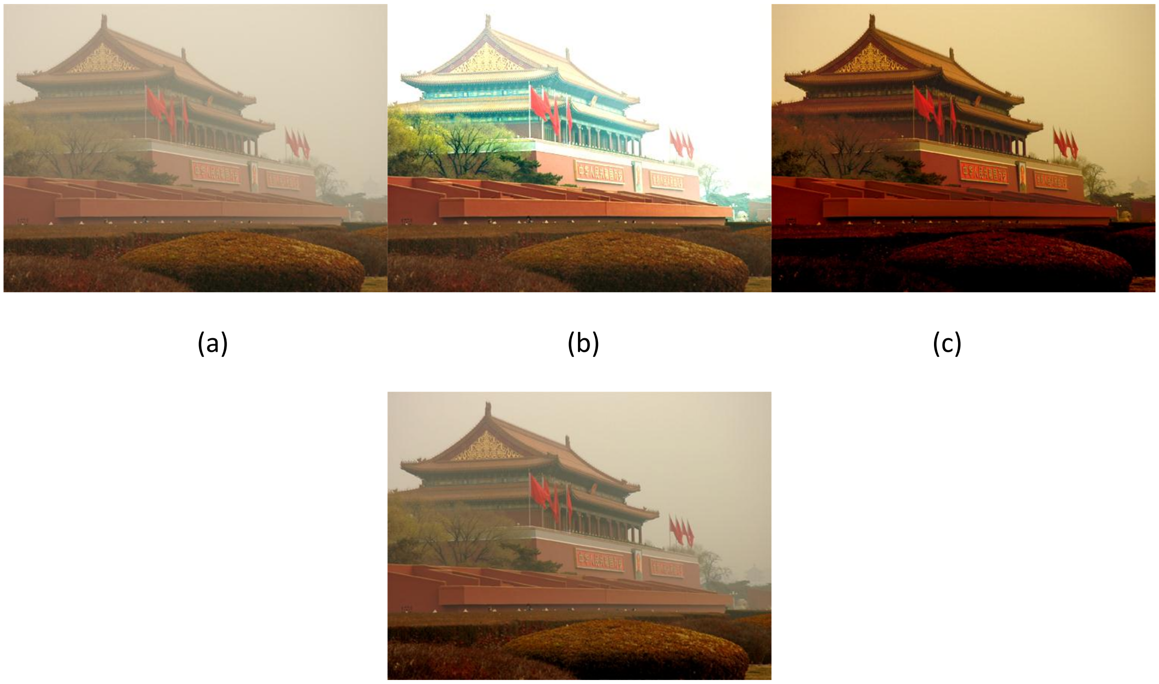
EXPERIMENTATION & EVALUATION

In this section, some of the latest single image defogging methods have been compared along with various image quality assessment metrics. The methodology used is from the Meng (Meng et al., 2013), Bovik (Choi et al., 2015), Cai (Cai et al., 2016), defogging algorithms. These techniques had been used because of its methodology used and secondly, these algorithms were latest in research. The dataset of 80 images had been used for different results. Here, out of 80 images we have shown results for 3 images. Figure 2 shows the input images namely: Adirondack_Hazy.bmp, Piano_Hazy.bmp, Tiananmen.png. Fig.3–Fig.5 shows the experimental results for the input images passed through Meng (Meng et al., 2013), Bovik (Choi et al., 2015), Cai (Cai et al., 2016) defogging algorithms and their quality criteria have also been evaluated. Table 2 gives the values of the density of the input images that have been produced through Bovik (Choi et al., 2015). Table 3-Table 8 shows the values of the fog density and image quality measures for the images Adirondack_Hazy.bmp, Piano_Hazy.bmp, Tiananmen.png respectively.



(a) (b) (c)

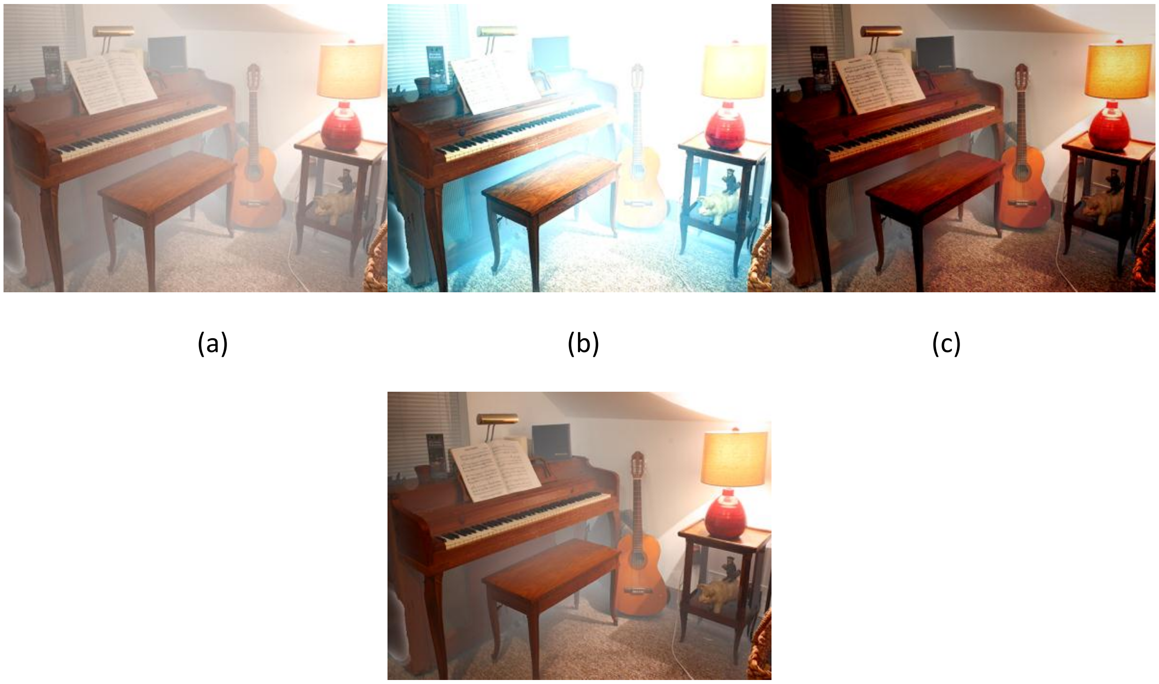
Fig 2 Input Images (a) Adirondack_Hazy.bmp (b) Piano_Hazy.bmp (c) Tiananmen.png



(a) (b) (c)

(d)

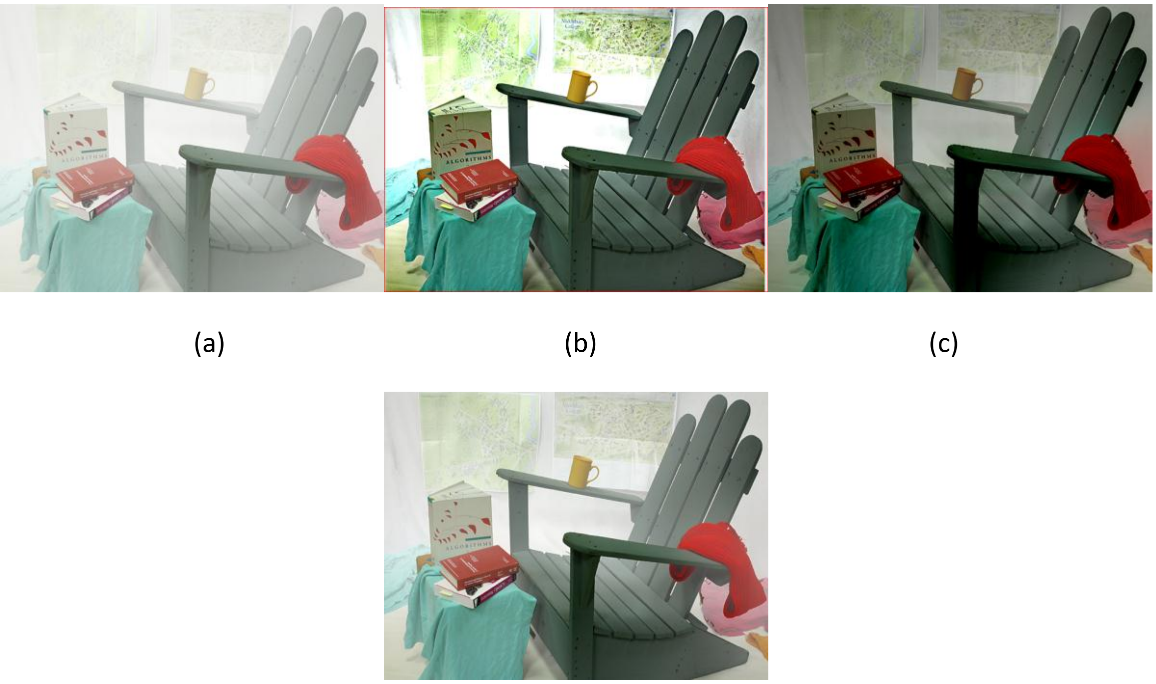
Fig 3: Results for input image “Adirondack_Hazy.bmp” (a) Original Image (b) Meng (Meng et al., 2013)Output (c) Bovik (Choi et al., 2015) (d) Cai (Cai et al., 2016)



(a) (b) (c)

(d)

Fig 4: Results for input image "Piano_Hazy.bmp" (a) Original (b) Meng (Meng et al., 2013)Output (c) Bovik (Choi et al., 2015) (d) Cai (Cai et al., 2016) (e) Galdran (Galdran, 2018) (f) Zhu (Mingzhu et al., 2019)



(a) (b) (c)

(d)

Fig 5: Results for input image "Tiananmen.png" (a) Original Image (b) Meng (Meng et al., 2013)Output (c) Bovik (Choi et al., 2015) (d) Cai (Cai et al., 2016)

Table 2: Results for Density of input image

S.No.	Input Image	Density
1	Adirondack_Hazy.bmp	2.6080
2	Piano_Hazy.bmp	1.5919
3	Tiananmen.png	1.3350

Table 3: Results for fog density for Adirondack_Hazy.bmp

Methodology Used	**Meng** (Meng et al., 2013)	**Bovik** (Choi et al., 2015)	**Cai** (Cai et al., 2016)
Density	0.7325	0.4978	1.2197

Table 4: Results for Meng (Meng et al., 2013), Bovik (Choi et al., 2015), Cai (Cai et al., 2016) defogging algorithms for Adirondack_Hazy.bmp

Quality Criteria	**Meng** (Meng et al., 2013)	**Bovik** (Choi et al., 2015)	**Cai** (Cai et al., 2016)
E	10.5492	12.7197	3.9395
$\bar{r}$	2.6925	1.8065	1.5038
IVM	0.1353	0.0434	0.0015
Contrast Gain	4.8942	5.1886	2.5490
VCM	-0.0636	-0.1891	0.3270
Σ	0.6979	0.6345	0.8845
HCC	0.2097	0.3422	0.0709
SSIM	54.8077	45	36.5385
UQI	0.7705	0.5573	0.8901
MSE	4.5320e+03	1.0180e+04	1.9683e+03
PSNR	11.5679	8.0535	15.1900
NK	0.7949	0.5203	0.8301
AD	48.6562	98.9742	38.0929
SC	1.4197	3.3552	1.4085
MD	184	179	102
NAE	0.2844	0.5086	0.1958

Table 5: Results for fog density for Piano_Hazy.bmp

Methodology Used	**Meng** (Meng et	**Bovik** (Choi et al., 2015)	**Cai** (Cai et al., 2016)

	al., 2013)		
Density	0.9559	0.3277	0.6871

Table 6: Results for Meng (Meng et al., 2013), Bovik (Choi et al., 2015), Cai (Cai et al., 2016) defogging algorithms for Piano_Hazy.bmp

Quality Criteria	**Meng** (Meng et al., 2013)	**Bovik** (Choi et al., 2015)	**Cai** (Cai et al., 2016)
E	8.4486	18.8014	11.6322
$\bar{r}$	2.3292	1.7014	1.3222
IVM	0.3024	0.0573	0.0342
Contrast Gain	5.4470	7.6403	5.0619
VCM	0.6406	-0.0822	0.6381
Σ	0.8232	0.6033	0.8692
HCC	0.0856	0.5590	0.1258
SSIM	41.3462	51.3462	35.7692
UQI	0.9341	0.5423	0.8186
MSE	2.0754e+03	7.3804e+03	2.7402e+03
PSNR	14.9598	9.4500	13.7529
NK	1.1827	0.5682	0.7488
AD	-29.0563	82.7257	48.9518
SC	0.6989	2.7058	1.7118
MD	75	173	97
NAE	0.2343	0.4826	0.2856

Table 7: Results for fog density for Tiananmen.png

Methodology Used	**Meng** (Meng et al., 2013)	**Bovik** (Choi et al., 2015)	**Cai** (Cai et al., 2016)	**Galdran** (Galdran, 2018)	**Zhu** (Mingzhu et al., 2019)
Density	0.5188	0.3545	0.7108	0.5355	0.4149

Table 8: Results for Meng (Meng et al., 2013), Bovik (Choi et al., 2015), Cai (Cai et al., 2016) defogging algorithms for Tiananmen.png

Quality Criteria	**Meng** (Meng et al., 2013)	**Bovik** (Choi et al., 2015)	**Cai** (Cai et al., 2016)
E	8.9773	7.2769	5.0969
$\bar{r}$	2.0907	1.3101	1.1778
IVM	0.3346	0.1110	0.0131
Contrast Gain	7.8016	5.8579	4.5783
VCM	-0.0393	0.0148	0.3249
Σ	0.8198	0.6289	0.9366
HCC	0.1188	0.6223	0.1977
SSIM	46.3462	60.7692	61.9231
UQI	0.9535	0.5635	0.9024
MSE	1.6290e+03	3.4882e+03	578.7584
PSNR	16.0117	12.7048	20.5058
NK	1.1946	0.7340	0.8850
AD	-23.3872	50.9816	21.4106
SC	0.6866	1.6339	1.2597
MD	97	111	49
NAE	0.2286	0.3533	0.1484

All the codes and the quality assessment metrics have been developed and tested on the same computer. The system is Win 7 ultimate, MATLAB software 2016 R; hardware is Intel Core i3 CPU and 4 GB RAM. In the paper (Bansal et al., 2017) we have already compared the single image dehazing methods namely: CLAHE, (Tarel & Hautiere, 2009), (He et al., 2010), (Kaiming et al., 2011). This paper is just an extension of the algorithms that have been concluded in the last few years. No defogging algorithm is best to serve in all conditions, so it’s difficult to say which could be the best algorithm.

CONCLUSION

This paper attempts to insight various single image dehazing techniques and employed all of them on MATLAB 2016 R. Although a lot of research had been done in the related field it still has space to cover more. It has been observed that no appropriate techniques embeds compression and dehazing. Negligible work has been attempted in this context. Moreover, generally, the haze-free images still suffer from basic problems of noise. So, an attempt can be made to remove the noise problems.

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