Performance Evaluation of Multiwavelet Transform for Single Image Dehazing

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Abstract. Images captured in poor lighting conditions (such haze, fog, mist, or smog) have a lower level of visibility because air particles deflect light. Single picture dehazing techniques can restore clarity to a single hazy image. Even though Dark channel prior (DCP) has been the most used method for image dehazing algorithms, it has poor picture quality and requires a lot of adjustments for real time applications such as; computer vision, object detection. However, previous studies such as; Dark Channel Prior (DCP) on image dehazing agonises from a gigantic processing time and sleaze of the original image. In addition, the dimensions of the images have a significant effect on the performance of the dehazing algorithms. Hence, the main motive of this work is to minimize the computational overload either by reducing the size of the image or by accurate transmission map estimation without compromising the image quality. Hence, this work is focused on reducing the computational time for image dehazing through multilevel discrete (Haar) wavelet transform, in which the image dimensions has been reduced without degrading quality. The performance measures of proposed algorithm have been analysed in terms of PSNR, MMSE and SSIM and compared with existing DCP algorithm. The simulation results proven that, the computational time for proposed algorithm has been reduced by 90% when compared to DCP without degrading image quality.

Keywords: Computational Time · Computer Vision · Dark Channel Prior · Dehazing · Image Dimension · Image Quality · Object Detection · Transmission map · Visibility · Wavelet Transform

1 Introduction

The pictures taken in outdoor sceneries frequently have haze, fog, or other atmospheric deterioration owing to medium particles that absorb and scatter light as it passages towards spectator. Due to this process, the quality will severely impair and which leads to immoral image quality. In contrast, a cloudy image is always detrimental to perception applications like tracking objects, observing the environment etc. To improve the image

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quality for visualization and analysis as well as retrieving meaningful information from contaminated images, it is very crucial to remove the negative element. The removal of haze from photographs can be accomplished using a variety of techniques [1].

The optics of a computer vision framework are for the most part planned utilizing the presumption of splendid weather patterns, where the shading power of every pixel is exclusively related with the brilliance of the first scene. Consequently, learns at a beginning phase of computer vision errands specifically overlooked the state of awful climate [2]. Nonetheless, specialists soon understood the significance of picture reclamation procedures. Outside pictures are unavoidably antagonistically affected by the circumstances, and refraction, scattering and maintenance occur indeed, even on moderately sunny mornings, bringing about loss of itemized data and low differentiation. These debased info pictures lead to unfavorable effects on independent frameworks [3]. The model of haze formation has been depicted in Fig. 1.

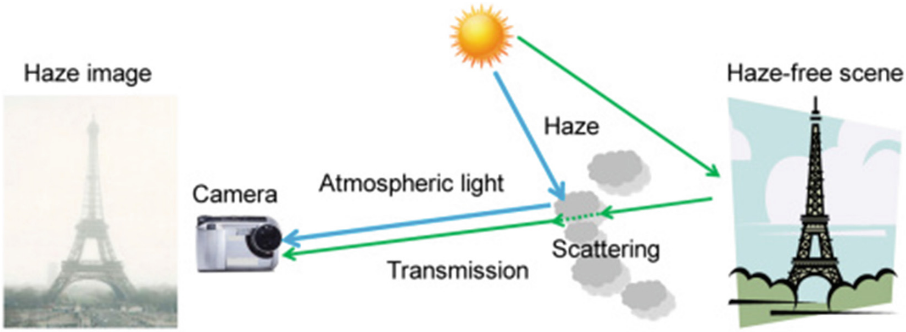

Fig. 1. Haze creation model [4].

Image dehazing with multiwavelet transform has a number of benefits over competing techniques [5]. The regularization elements of the optimization formulation can therefore enable flexibility in computing the dehazing solution by using a priori knowledge of the image and the atmospheric light transmission distribution, directing the computation to a desirable conclusion. Due to these benefits, high-quality dehazing performance can be achieved in a short amount of time. Hence, this work focuses on developing an algorithm for dehazing of images with high accuracy and less computational time by maintains adequate picture quality [6, 7].

2 Related Work

Most single picture dehazing calculations utilize either prior based picture handling determined to anticipate the broadcast, while deducing the barometrical light by exact techniques. A critical headway has the disclosure in [8], one channel that has an immaterial power among concealing coordinates in non-sky areas. The proposed algorithm in [9] offers the potential gains of straight inconvenience and feasibility yet moreover has drawbacks in flexibility, speed, and edge assurance, impelling numerous endeavors to manage the essential method.

The authors in [10] have consolidated the dehazing methodologies to move along the computational time. Thusly, two or three papers [11–14] credited the long dealing with season of the essential dehazing procedure to the delicate matting development, supplanting it with different channels. More of late, morphological redirection has partaken in the dehazing collaboration, vanquishing the absence of detail accomplished by the base channel [15]. The authors in [16] presented a joint improvement between equipment and calculation, accomplishing ongoing handling with restricted corruption. A new report [17] utilized a book unaided learning strategy by means of minimization of the computational time, taking care of the organization with certifiable cloudy pictures as opposed to ordinarily utilized engineered information to keep away from the conceivable space shift. In [18], the authors have presented an algorithm, accepting the brilliance and immersion are significantly different by the fog focus. In [19], a non-neighborhood dehazing (NLD) calculation for single pictures has been proposed. As indicated by their perceptions, the quantity of tones is a lot more modest than the quantity of pixels in a picture.

All through the advancement of knowledge-based dehazing approaches, the longing for elite execution has driven the advancement of progressively complex procedures, for example, multi-scale designs. This pattern has decreased the commonsense utilization of single picture dehazing algorithms, specifically for asset obliged applications where ongoing activity with restricted computational assets is a key driver. Numerous new investigations based on Arduino integrated with IOT [20–24] perceive the requirement for ongoing handling and the advancement of methods to lessen the capacity, intricacy, handling time and other related angles without compromising the presentation. The proposed image dehazing algorithm mainly focused on reducing the dimensions of the image through multiwavelet transform there by achieving the less computational time when compared to DCP algorithm by maintain bearable picture quality.

3 Methodology

The primary disadvantage in DCP method is its computational time. Pragmatic applications require less opportunity to compute the dehazed picture from haze pictures. To beat this downside a superior adaptation of DCP calculation which is a Fast DCP has been proposed for dehazing of images. Image dehazing based on DCP method [25] in which the transmission medium $t'(x)$ is determined by utilizing confined area. In this way, the border area has been unbending for $t'(x)$. To smoothen these edges the algorithm utilized transmission map refinement, which is a tedious interaction and does not appropriate for pragmatic applications. The haze image is a combination of image coordinates, observed image, haze free image, atmospheric light, scattering coefficient and scene depth [24], which is represented using (1). The dark channel from the input hazy image is estimated by the majority of traditional DCP-based dehazing techniques and it is represented using (2).

$$I_{haze}(x) = J_{haze-free}(x)e^{-\beta d(x)} + A\left(1 - e^{-\beta d(x)}\right) \tag{1}$$

$$J^{dark}(x) = \min_{y \in \Omega(x)} \left(\min_{c \in \{r,g,b\}} J^{c}(y) \right) \tag{2}$$

3.1 Image Model

The hazed image has two additive components. The first element, or clear image, is made up of light that has been reflected off of an object's surface. The scattering transmission, or haze, is the second component. The optical model of an image can be expressed using (3).

$$I_c = J_c \odot t + a_c(1 - t), c = 1, 2, 3 \ldots \tag{3}$$

3.2 Sub-band Image Model

Using DHWT to quickly break down the image model into a bank of frequency sub bands based on the low pass characteristic of the light broadcast dispersal. Thus, the information about t is already included in the decomposed picture model in the low-frequency region and may be used to estimate it. The computing complexity of the dehazing process can be significantly decreased by using this sub-band image model with a smaller size. For example, t can be characterized by means of (4) when the atmosphere is homogeneous.

$$t = e^{-\beta d} \tag{4}$$

Based on discrete haar wavelet transform, the sub-band image model can be expressed using (5) based on the approximate 2-D matrix dimension W.

$$\mathrm{W}^{\mathrm{n}}_{\mathrm{p,q}} = {}^{1}\!\big/\!\sqrt{2^{\mathrm{k-p}}} \text{ if } \mathrm{q} \times 2^{\mathrm{k-p}} \le \mathrm{n} < \left(\mathrm{q} + \frac{1}{2}\right) \times 2^{\mathrm{k-p}} \tag{5}$$

4 Simulation Results

4.1 Subjective Analysis

The simulation has been performed using MATLAB with 1.5 GHz operating frequency. Firstly, the optical model of the input hazy image has been estimated. The subjective analysis has been carried out for various hazy images (see Fig. 2).

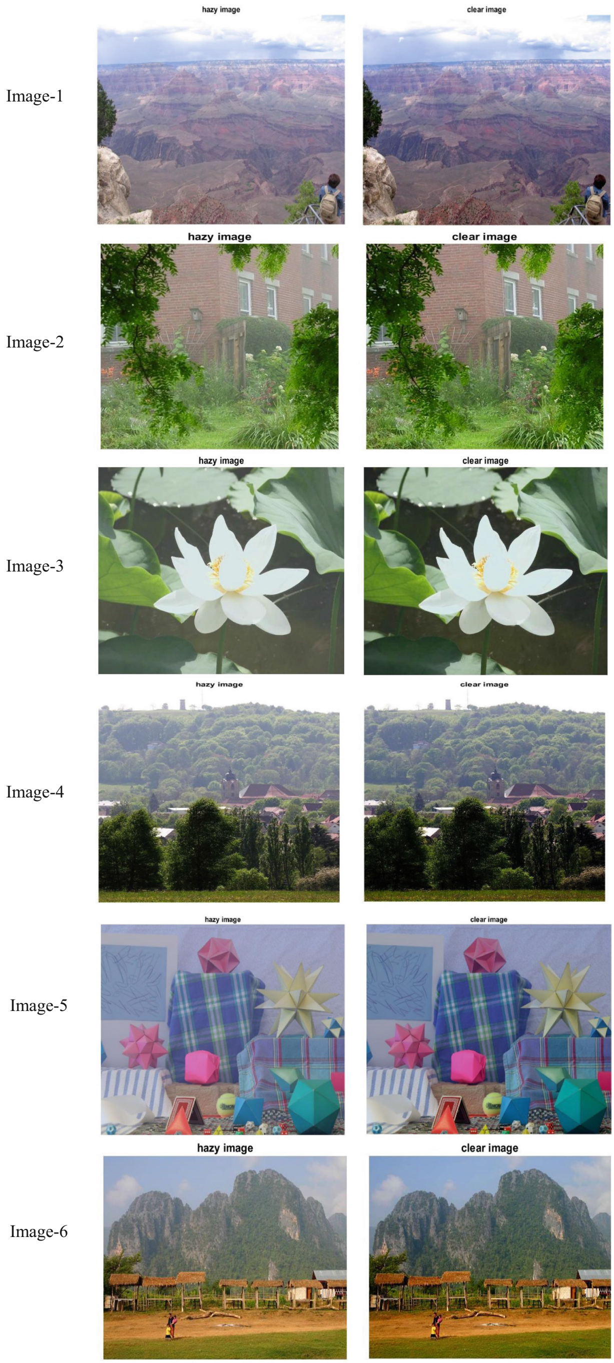

Fig. 2. Simulation results of proposed dehazing algorithm for various haze images.

After estimating the optical model of an image, the image transmission distribution has been estimated. By keeping both the values of scene depth d and β are positive, the transmission distribution t has been evaluated. Then, the sub-band image model has been created with reduced dimension of the image for achieving less computational time. Subjective analysis is the analysis which uses the observers to make the quality estimation based on their visual opinion of the image.

4.2 Objective Analysis

The objective analysis has been conducted for the proposed methodology in terms of PSNR, MSE and computational time. The detailed analysis has been depicted in Table 1. The PSNR and mean square error has been evaluated using Eqs. (6) and (7) respectively.

$$PSNR = 20\log(\frac{Max}{\sqrt{MSE}}) \tag{6}$$

$$MSE = \frac{1}{MM}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \tag{7}$$

Table 1. Comparison of MSE, PSNR and SSIM values of DCP and DHWT algorithms for various images

Image name	Parameter	DCP	DHWT
Image-1	MSE	0.0087	0.0073
	PSNR	62.7544	69.5266
	SSIM	0.8341	0.9654
Image-2	MSE	0.0065	0.0039
	PSNR	68.4634	72.2325
	SSIM	0.8535	0.9689
Image-3	MSE	0.0079	0.0098
	PSNR	66.7544	68.2286
	SSIM	0.7986	0.9316
Image-4	MSE	0.0092	0.0083
	PSNR	67.8243	68.9305
	SSIM	0.8742	0.8917
Image-5	MSE	0.0079	0.0069
	PSNR	63.4570	69.7550
	SSIM	0.8721	0.9649
Image-6	MSE	0.0069	0.0068

(*continued*)

Table 1. (*continued*)

Image name	Parameter	DCP	DHWT
	PSNR	69.9675	69.8259
	SSIM	0.9436	0.9368

Along with the objective analysis; the computational complexity has been estimated for both the algorithms (see Table 2).

Table 2. Comparison of computational time.

Image name	DCP (s)	Proposed (s)
Image-1	9.874	0.6688
Iamge-2	9.774	0.3388
Image-3	9.869	0.5840
Image-4	10.057	0.8681
Image-5	9.877	1.4269
Image-6	8.7675	0.4528

5 Conclusion

Image dehazing expulsion techniques have become more valuable for many picture handling and computer vision applications. All the dehazing techniques helpful for reconnaissance, for remote detecting and submerged imaging, photography and so forth A large portion of the techniques depend on the assessment of climatic light and transmission map. In, this work a DHWT for dehazing the images have been proposed. The proposed method performs the dehazing without degrading the picture quality and with less computational time when compared to DCP for single image dehazing.

References

1. Kermani, E., Asemani, D.: A robust adaptive algorithm of moving object detection for video surveillance. EURASIP J. Image Video Process. **2014**(1), 1–9 (2014)
2. Ozaki, M., Kakimuma, K., Hashimoto, M., Takahashi, K.: Laser-based pedestrian tracking in outdoor environments by multiple mobile robots. In: Proceedings of Annual Conference on IEEE Industrial Electronics Society, pp. 197–202. IECON, Melbourne (2011)
3. Lee, S., Yun, S., Nam, J.-H., Won, C.S., Jung, S.-W.: A review on dark channel prior based image dehazing algorithms. EURASIP J. Image Video Process. **2016**(1), 1–23 (2016)
4. Anwar, M.I., Khosla, A.: Vision enhancement through single image fog removal. Eng. Sci. Technol., Int. J. **20**(3), 1075–1083 (2017)

5. Badhe, M.V., Prabhakar, L.R.: A survey on haze removal using image visibility restoration technique. Int. J. Comput. Sci. Mob. Comput. **5**(2), 96–101 (2016)
6. Cai, B., Xu, X., Jia, K., Qing, C., Tao, D.: Dehazenet: an end-to-end system for single image haze removal. IEEE Trans. Image Process. **25**(11), 5187–5198 (2016)
7. Gibson, K.B., Vo, D.T., Nguyen, T.Q.: An investigation of dehazing effects on image and video coding. IEEE Trans. Image Proces. **21**(2), 662–673 (2012). https://doi.org/10.1109/TIP.2011.2166968
8. He, K., Sun, J., Tang, X.: Single image haze removal using dark channel prior. Pattern Anal. Mach. Intell. IEEE Trans. **33**(12), 2341–2353 (2011)
9. Gibson, K.B., Nguyen, T.Q.: On the efectiveness of the Dark Channel Prior for single image dehazing by approximating with minimum volume ellipsoids. In: IEEE international conference on acoustics, speech, and signal processing (ICASSP), pp. 1253–1256 (2011)
10. Xie, B., Guo, F., Cai, Z.: Improved single image dehazing using dark channel prior and multi-scale retinex. In: Proceedings of international conference on intelligent system design and engineering application. IDEA 2010, pp 848–851 (2018)
11. Park, D., Han, D.K., Ko, H.: Single image haze removal with WLS-based edge-preserving smoothing flter. In: IEEE International conference on acoustics, speech and signal processing (ICASSP), pp. 2469–2473 (2013)
12. Gibson, K.B., Nguyen, T.Q.: Fast single image fog removal using the adaptive Wiener flter. In: IEEE international conference on image processings, ICIP, pp. 714–718 (2013)
13. Xiao, C., Gan, J.: Fast image dehazing using guided joint bilateral flter. Vis. Comput. **28**, 713–721 (2012)
14. Zhang, Q., Li, X.: Fast image dehazing using guided flter. In: IEEE 16th international conference on communication technology (ICCT), pp. 182–185 (2015)
15. Salazar-Colores, S., et al.: A fast image dehazing algorithm using morphological reconstruction. IEEE Trans. Image Proc. **28**(5), 2357–2366 (2019)
16. Lu, J., Dong, C.: DSP-based image real-time dehazing optimization for improved dark-channel prior algorithm. J. Real-Time Image Proc. **17**(5), 1675–1684 (2019)
17. Golts, A., Freedman, D., Elad, M.: Unsupervised single image dehazing using dark channel prior loss. IEEE Trans. Image Proc. **29**, 2692–2701 (2020)
18. Zhu, Q., Mai, J., Shao, L.: A fast single image haze removal algorithm using color attenuation prior. Image Process. IEEE Trans. **24**(11), 3522–3533 (2015)
19. Berman, D., Treibitz, T., Avidan, S.: Non-local image dehazing. In: Computer vision and pattern recognition (CVPR), pp. 1674–1682 (2016)
20. Bhaavan Sri Sailesh, A., Sudha Madhavi, A., Venkata Pavan, G., Sravanthi, I., Karthik Sai Kiran, B., Venkateswara Rao, Ch.: Arduino based smart street light system. In: 2021 3rd International Conference on Advances in Computing, Communication Control and Networking (ICAC3N), pp. 657–660 (2021)
21. Venkateswara Rao, Ch., Pathi, M.V.A., Sailesh, B.S.A.: Arduino based electronic voting system with biometric and GSM features. In: 2022 4th International Conference on Smart Systems and Inventive Technology (ICSSIT), pp. 685–688 (2022)
22. Chand, R.P., Sri, V.B., Lakshmi, P.M., Chakravathi, S.S., Veerendra, O.D.M., Rao, C.V.: Arduino based smart dustbin for waste management during Covid-19. In: 2021 5th International Conference on Electronics, Communication and Aerospace Technology (ICECA), pp. 492–496 (2022)
23. Shaik, A.R., Chandra, K.R., Raju, B.E., Budumuru, P.R.: Glaucoma identification based on segmentation and fusion techniques. In: 2021 International Conference on Advances in Computing, Communication, and Control (ICAC3), pp. 1–4 (2021)

24. Budumuru, P.R., Kumar, G.P., Raju, B.E.: Hiding an image in an audio file using LSB audio technique. In: 2021 International Conference on Computer Communication and Informatics (ICCCI), pp. 1–4 (2021)
25. Iwamoto, Y., Hashimoto, N., Chen, Y.-W.: Fast dark channel prior based haze removal from a single image. In: 2018 14th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), pp. 458–461 (2018)