Dehazing of Satellite images using DWT

[1]M.Vasudeva Reddy, [2]Dr.T.Ramashri
[1]Research Scholar, Rayalseema University,Kurnool, Andhra Pradesh, India.
[2] Professor, S.V.University, Tirupati, Andhra Pradesh, India

Abstract - **Haze in remotely sensed images usually degrades the visual information, which paves way for the development haze removal algorithms to improve visual multispectral information. The literature reveals that haze removed images have problems like colour distortion, halo artifacts, etc. To overcome these problem, the concepts of wavelet transforms are used in this paper to restore the haze free images. As the haze is mostly distributed in the lower frequencies which as a layer may contain the components of land cover which are stable both spatially and temporally, the use of Discrete Wavelet Transform proves to be appropriate for dehaing. The experimental results reveal that this approach provides visually significant haze-free images by preserving the significant details.**

***Index Terms*: Haze, Dehazing, Discrete Wavelet Transform, Dark Channel Prior, Haar wavelet.**

I. Introduction

Haze represents the fog, mist, or other atmospheric phenomena which degrades outdoor images by reducing visibility in terms of both color and contrast. It is mainly generated by atmospheric scattering, usually modeled by using Mie theory which is caused by larger particles like dust, smoke, pollen grains, water droplets, etc. As Mie scattering is wavelength dependent, hence for some environmental conditions near to short wavelengths, more particles occur in the atmosphere, resulting in visually detectable haze [1] [2].

The spatial distribution of the particles depends on weather conditions and the location of dust sources, which will be slower (on the scale of kilometers) than for land cover which changes at higher frequencies. Hence the low spatial frequency component is dominated by haze, while the high frequency components reflect the effect of land cover of satellite images with a spatial resolution of less than 100 m, like in Landsat, IRS sensor payloads, etc. Also the haze contamination is most pronounced in the visible bands, and is weaker or visually undetectable in the nearer shortwave- infrared parts of the spectrum. This frequency dependancy paves way for using the wavelets for dehazing algorithms [3] [4].

The images suffer from poor quality due to undesirable quantization artifacts and noises in heavily hazy regions or sky patches or even lose the original spectral or structural information. To overcome these problems, we propose a discrete wavelet transform based high quality image dehazing algorithm.

This paper is organized as follows: section II deals with the literature survey of dehazing algorithms. The section III details with the proposed algorithm. The section IV shows the corresponding results followed by detailed discussion and finally the paper is concluded.

II. Existing Dehazing Algorithms

From literature, many authors proposed algorithms that helped the society to use practically in many applications. Earlier the problems were not only with satellite images, but also for railways where the track was not visible during heavy fog or mist conditions, in medical applications where the image captured by the camera used while doing operation usually happened to be dark and not clear, etc.

Due to the algorithms developed for Haze removal, all of these societal problems were solved to some extent. As Haze removal depends on the unknown depth information which changes at different locations. Earlier dehazing algorithms mainly exploit multiple images or extra information to recover the hazy image. Multiple images based dehazing methods remove the haze through handling two or more input images taken with different degrees of polarization filtered images [5], [6] or the same scene under different weather conditions [7], [8].

Another depth-based dehazing techniques [9], [10] make use of scene depth information from known three-dimensional (3D) models or user inputs. But these methods impose limitations in real applications due to extra information or as multiple input images are not always available in databases. Hence restoration from a single image proved to be more attractive.

Some researchers aimed at increasing the contrast and improving the color from the viewpoint of image enhancement like histogram-based [11], contrast based [12], fusion-based [13] [14] and so on. Unfortunately, enhancement-based dehazing methods cannot fully remove the haze owing to failing to consider image degradation mechanism.

By contrast, physics-based dehazing algorithms first construct the haze imaging model, then estimate unknown parameters, and finally inverse the physical model to obtain the haze-free image starting from the reason of image degradation.

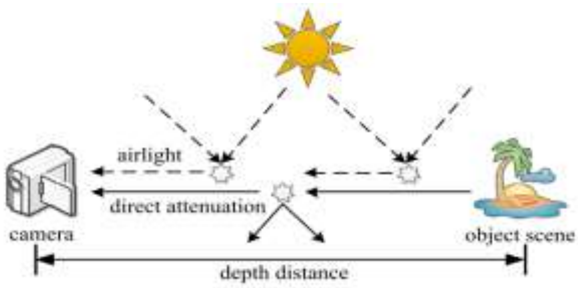

Fig.1: A Schematic Representation of Atmospheric Scattering Model

The schematic description of atmospheric scattering model is shown in figure 1[14]. The solid lines describe the direction attenuation part and dotted lines describe the air light part, respectively.

III. Proposed Dehazing Algorithm

Discrete Wavelet Transform (DWT) of image produces a non-redundant image representation, which provides better spatial and spectral localization of image formation compared with other multi scale representation such as Gaussian and Laplacian pyramid. The DWT can be interpreted as signal decomposition in a set of independent spatially oriented frequency channels. The signal S id passed through two complementary filters and emerges a two signals. approximation and details. This is called decomposition or analysis. The components can be associated back into the original signal without loss of information. This process is called reconstruction or synthesis. The mathematical manipulation, which implies analysis and synthesis, is called Discrete Wavelet Transform and Inverse DWT.

The DWT represents an image as a sum of wavelet functions, known as wavelets, with different location and scale. It represents the data into a set of high pass (detail) and low pass (approximate) coefficients. The input data is passed through set of low pass and high pass filters. Filter kernel used for this research work is $\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$. The output of high pass and low pass filters are down sampled by 2. The output from low pass filter is an approximate coefficient and the output from the high pass filter is a detail coefficient. This procedure is one dimensional (1-D) DWT and Figure 2 shows the schematics of this method.

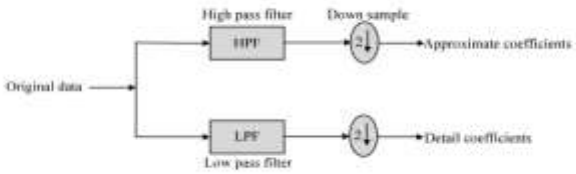

Fig. 2: Block Diagram of 1D forward DWT

In case of 2-D DWT, the input data is passed through set of both low pass and high pass filter in two directions, both rows and columns. The outputs are then down sampled by 2 in each direction as in case of 1-D DWT. The complete process is illustrated in Figure 3. As shown in Figure 3, output is obtained in set of four coefficients LL, HL, LH and HH. The first alphabet represents the transform in row where as the second alphabet represents transform in column. The alphabet L means low pass signal and H means high pass signal. LH signal is a low pass signal in row and a high pass in column. Hence, LH signal contain horizontal elements. Similarly, HL and HH contains vertical and diagonal elements, respectively.

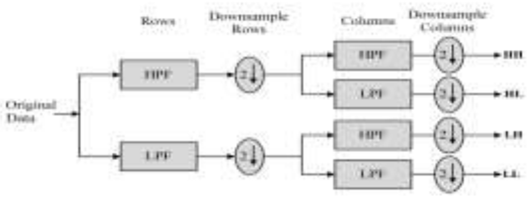

Fig. 3: Block Diagram of 2D forward DWT

In DWT reconstruction, input data can be achieved in multiple resolutions by decomposing the LL coefficient further for different levels as shown in Figure 4 In order to reconstruct the output data, the compressed data is up-sampled by a factor of 2. The signal is further passed through the same set of high pass and low pass filter in both rows and columns. The entire reconstruction procedure is shown in Figure 5.

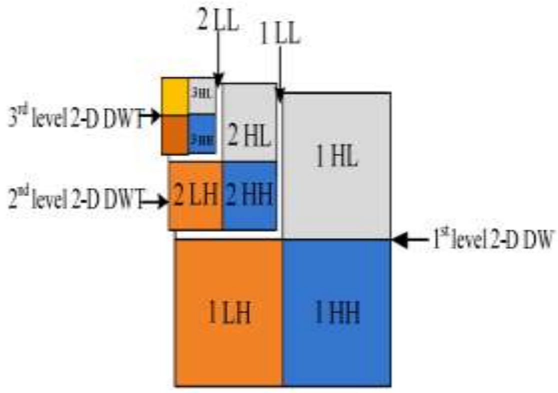

Fig. 4: Multilevel Forward DWT

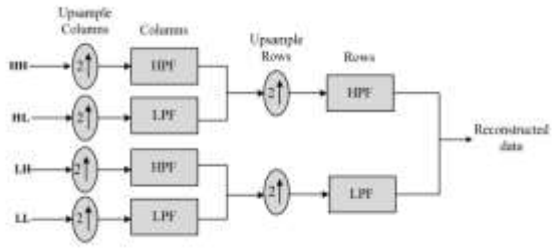

Fig. 5: Block Diagram of 2D Inverse DWT

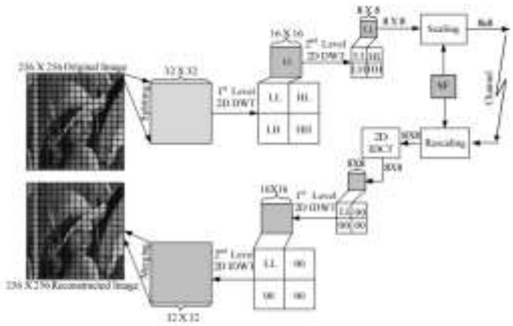

Fig.6: Block Diagram of DWT Decomposition

The process continues for one more level. The coefficients are then divided by a constant scaling factor (SF) to achieve the desired compression ratio. Finally, for data reconstruction, the data is rescaled and padded with zeros, and passed through the wavelet filters. The entire process of 2-D DWT compression and reconstruction is shown in Figure 6.

The algorithm is as follows:

Step 1: Read the satellite remote sensed image as input. Extract its size. Change the size to double.

Step 2: Apply Dark Channel Prior to the input image.

Step 3: Adjust the contrast of the image.

Step 4: Apply Haar Wavelet Transform and obtain the Output dehazed image.

The above mentioned algorithm is coded in matlab and tested for satellite images.

IV. Results and Discussion

The performance of the proposed algorithm is verified on several satellite remote sensed images. The algorithm has been implemented and verified using Matlab. The performance parameters [10] such as Mean Absolute Error, Mean Square Error, and Peak Signal to Noise Ratio and Signal to Noise Ratio are calculated for the restoration of dehazed images as shown in figures 7, 8, 9, 10 and 11. The left most image represents the input image with haze, the middle image represents the dark channel prior dehazed image and the right most image represents the DWT processed dehazed image.

Fig. 7: Input and Output Images for input image - 1.

Fig. 8: Input and Output Images for input image - 2.

Fig. 9: Input and Output Images for input image - 3.

Fig. 10: Input and Output Images for input image - 4.

Fig. 11: Input and Output Images for input image - 5.

The output images of DWT prove to be more clear than the dark channel prior processed images. Further the results are evaluated for various parameters like Mean Square Error, Peak Signal to Noise ratio, Coefficient of variance, structural Similarity index and mean Structural Similarity index which are consolidated in table 1.

Table - I: Comparison of proposed algorithm for various Parameters

Parameters	Image1	Image2	Image3	Image4	Image5
Mean Square Error	598.5131	2.6497e+03	5.0524e+03	1.6866e+04	4.6474e+03
Peak Signal to Noise Ratio	20.3601	13.8988	11.0958	5.8606	11.4587
Coefficient of Variance	2.6567e+03	188.7799	343.8651	200.7562	332.8755
Structural Similarity Index	0.1087	0.1168	0.0813	0.3431	0.2358
Mean Structural Similarity	0.2692	0.2732	0.2611	0.4465	0.4151

From Table - I, the proposed algorithm proves to be a better choice for dehazing satellite images as the parameters show significant improvement.

V. Conclusion

Haze is caused by atmospheric scattering, modeled as mie scattering depends on wavelength. The hazed images are usually blurr and are not visible properly. The dehazing algorithms mainly focus on contrast and colour enhancement by removing the articrafts. Many algorithms fail as they consider the hazing as wavelength or frequency independent. The proposed algorithm focuses on this aspect and proved to be a better choice due to usage of discrete wavelet transform for recovering the information contained in the lower frequency bands. The algorithm was evaluated for parameters like Mean Square Error, Peak Signal to Noise ratio, Coefficient of variance, structural Similarity index and mean Structural Similarity index for proving it's efficiency.

References

1. S. G. Narasimhan and S. K. Nayar, “Contrast restoration of weather degraded images,” IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 25, no. 6, pp. 713–724, 2003.

2. S. G. Narasimhan and S. K. Nayar, “Vision and the atmosphere,” International Journal of Computer Vision, vol. 48, no. 3, pp. 233–254, 2002.

3. Y. Y. Schechner, S. G. Narasimhan, and S. K. Nayar, “Instant dehazing of images using polarization,” in Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR '01), vol. 1, pp. 325–332, IEEE, Kauai, Hawaii, USA, 2001.

4. J. G. Walker, P. C. Y. Chang, and K. I. Hopcraft, “Visibility depth improvement in active polarization imaging in scattering media,” Applied Optics, vol. 39, no. 27, pp. 4933–4941, 2000.

5. J. Kopf, B. Neubert, B. Chen et al., “Deep photo: model-based photograph enhancement and viewing,” ACM Transactions on Graphics, vol. 27, no. 5, article 116, 2008.

6. K. He, J. Sun, and X. Tang, “Single image haze removal using dark channel prior,” in Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR '09), pp. 1956–1963, IEEE, San Francisco, Calif, USA, June 2009.

7. C. X. Xiao and J. J. Gan, "Fast image dehazing using guided joint bilateral filter," Visual Computer, vol. 28, no. 6–8, pp. 713–721, 2012.

8. J. W. Zhang, L. Li, G. Q. Yang, Y. Zhang, and J. Z. Sun, "Local albedo-insensitive single image dehazing," Visual Computer, vol. 26, no. 6-8, pp. 761–768, 2010.

9. C. O. Ancuti and C. Ancuti, "Single image dehazing by multi-scale fusion," IEEE Transactions on Image Processing, vol. 22, no. 8, pp. 3271–3282, 2013.

10. Z. Wang and Y. Feng, "Fast single haze image enhancement," Computers and Electrical Engineering, vol. 40, no. 3, pp. 785–795, 2014.

11. Manisha A. Wakure, Dr. Anilkumar N. Holambe," A Steganographic Method for Transmitting Images Based on Discrete Wavelet Transform Using Three Level and Single Level Wavelet Decomposition" in International Journal of Advanced Research in Computer Science and Software Engineering, Volume 6, Issue 3, March 2016.

12. Mingye Ju, Zhenfei Gu, Dengyin Zhang, and Haoxing Qin, " Visibility Restoration for Single Hazy Image Using Dual Prior Knowledge", Hindawi Mathematical Problems in Engineering Volume 2017, Article ID 8190182, 10 pages.

13. Dilbag Singh, Vijay Kumar," Dehazing of outdoor images using notch based integral guided filter ", Multimedia Tools and Applications, October 2018, Volume 77, Issue 20, pp. 27363-27386.

14. Yun Liu, Jinxia Shang, Lei Pan, Anzhi Wang, and Minghui Wang, " A Unified Variational Model for Single Image Dehazing ", IEEE Access 2019, Volume 7, pp. 15722-15736.