Research Article

In-depth Analysis of Contemporary Grayscale Image Dehazing Methods: A Comprehensive Review

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Abstract: Since the fog results in loss and color distortion in an image under poor weather circumstances, an efficient image defogging algorithm is required for retrieving various details in an image and hence recovery of a true color information for visibility improvement. In this paper several state-of-art techniques designed by different researchers towards solving this problem in order to enhance the image by improving the existing present-day approaches have been presented. Various enhancements in this area are suggested to increase the value of quality parameters which leads to a better defogged image and hence decreases the road accidents existing day by day. Several intelligent techniques including Q-Deep learning methods with other computer vision algorithms have been suggested to improve upon the visibility of the foggy scene. Finally, the whole review has been concluded by pointing out the several advantages and shortcomings of the existing literature.

Keywords: Deep learning, Artificial Intelligence, Fusion, Thermal Analysis

1. Introduction

When capturing an image in foggy weather conditions, the results frequently suffer from low visibility. The far-off objects in the fog lose their contrasts and blends with their surroundings because the reflected light from these objects is attenuated in the air before reaching the camera and are combined with atmospheric light dispersed by various aerosols (e.g., dust and water droplets). The colors of these objects fade and become quite similar to fog, the degree of resemblance depends on the distance between the camera and the object. This makes it more difficult to detect objects under observation, which contributes to an increase in road accidents. Fog-related vehicle accidents killed 7,665 individuals in 2015. This figure increased to 9,317 fatalities in 2016 leads to the increase in death rate by 20%. According to 2017 data from the Ministry of Road Transport and Highways (MORTH) [1], Uttar Pradesh had the most fog-related road fatalities (3,374), followed by Bihar (1,432), Haryana (900), Punjab (866), and Orissa (516). In the year 2018 as compared to 2017, the maximum increase in road accidents (19.9%) and road accident deaths (13.2%) has been observed under foggy weather condition. The graph below depicts the number of road accidents occurred due to fog in India.

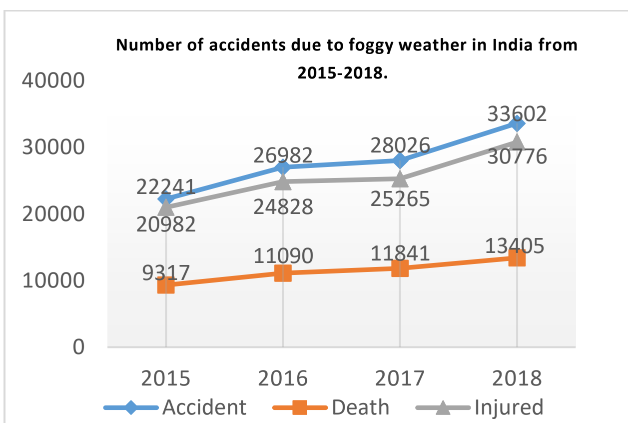

Fig. 1. Year-wise Date of Accidents due to fog from 2015-2018

As a result, an effective image defogging method is required to improve the perceptibility and contrast of the acquired degraded image. Several visible Image defogging approaches are used by various researchers to defog the image efficiently however there is a need to improve the existing algorithm by using the computer vision algorithm.

1.1. Literature Survey

Section below described the literature survey of existing defogging methods employed by different researchers along with their advantages and shortcomings.

Authors in [2] have presented a learning-based approach for visible and thermal image fusion that focuses on creating fused images with good visual resemblance to conventional true color (RGB) images while incorporating new useful information in pedestrian zones. The idea is to provide natural, intuitive visuals that are more instructive to a human driver in low-visibility situations than a standard RGB camera. The idea of relying on two types of objective functions for optimization is novel in this proposed scheme. Primarily a similarity metric between the RGB input and the fused output to achieve natural image appearance; and an auxiliary pedestrian detection error to help define relevant features of the human appearance and blend them into the output. A Convolutional Neural Network has been trained utilizing image features from various scenarios to understand the occurrence of people in various modalities and provide robust findings that can be applied in real-world framework. The results reveal that pedestrian vision is significantly increased by the proposed technique, particularly in gloomy areas and at night. The context and build fusion rules focus on the pedestrian pattern better than existing approaches, which is not guaranteed with other state-of- art methods that mainly focuses on low-level picture quality measures The fused images provide more information to the detectors and increase their recognition accuracy. The proposed approach is not multi-scale generative network required for strong content modelling.

Authors in [3] have proposed a Convolutional Neural Network (CNN) based infrared and visible image fusion technique for improving the illumination of scene. A Siamese Convolutional Neural Network is used in particular to create a weight map that combines the pixel activity information from two source images. The CNN-based method takes into consideration two techniques for image fusion: estimation of activity level of pixels in an image and the assignment of weights. The merging operation is carried out in a multi-scale manner using convolution-based image pyramids. In this proposed scheme various modalities of an infrared and visible image have been taken into account and a local similarity-based technique has been employed to adaptively alter the fusion mode for the decomposed coefficients of an image. The technique results in the improvement of an image in terms of both visual quality and objective assessment as compared to existing contemporary techniques. The overall network has architectural complexity.

A multi-resolution image fusion measure based on Visual Information Fidelity (VIF) is proposed by authors in [4] to objectively quantify fusion performance. There are four phases to this method: Firstly, images from the source and the fusion process are filtered and separated into blocks, followed by analysing visual information in each block with and without distortion information. The Information Fidelity of each sub-visual band for the fusion is calculated which is weighted to determine the overall quality measures. Using the subjective test dataset supplied by Petrovic, the proposed fusion assessment approach is compared to many other fusion metrics for performance analysis. Image fusion metric based on visual information fidelity (VIF) has high performance for image quality prediction. The algorithm, however, still has a scope for improvement in time and computational capability so that a better fusion technique can be designed.

In [5] the author has proposed a method in which the fusion of several images by weighted average has been performed, using the weights computed by the Cross Bilateral Filter (CBF) algorithm from the detail images. The performance of the proposed scheme was tested on numerous pairs of multi-sensor and multi-focus images. The technique was visually and statistically compared to other approaches and none of the techniques performed consistently across all performance criteria. CBF extracts detailed images from the source images by computing weights, which makes the algorithm easy to implement. The performance can be increased by using non-linear filters and by using other alternative method of calculating weight matrix.

An efficient regularization approach is being employed by researchers in [6] to eliminate haze from an RGB image. This technique has numerous benefits apart from exploration of the transmission function by underlying boundary limitations. These limitations are transformed into an optimization technique to estimate the unknown scene transmission, together with a weighted L1 norm based contextual regularization. These optimization issues can also be solved using an efficient technique of variable splitting. Only a few broad assumptions are required for the proposed technique to reconstruct a high-quality haze-free image with authentic colors and fine image details. The suggested method has best efficiency as demonstrated by experimental results on a range of hazy images. The proposed algorithm still has a scope of improvement by using a tighter radiance envelop to offer a more precise limitation on the transmissions.

Dehaze Net, a trainable end-to-end system for medium transmission estimation is used in the research put forth in [7]. Dehaze Net analyses a hazy image and produces a medium transmission map, which is then utilized to recover a haze-free image using an atmospheric scattering model. Dehaze Net uses a deep architecture based on Convolutional Neural Networks (CNN), with layers that are specifically designed to represent the established assumptions/priors in image dehazing. For feature extraction, layers of Maxout units are utilized, which may yield practically all haze-relevant characteristics. In Dehaze Net, Bilateral Rectified Linear Unit (BReLU), a unique nonlinear activation function has also been represented that can increase the quality of the reconstructed haze-free image. Dehaze Net relates the elements of proposed algorithm with pre-existing techniques to achieve the better dehazed image. The technique uses the atmospheric scattering model and transmission map at the cost of computation and memory consumption, hence reducing the processing speed.

The author in [8] describes a novel image dehazing approach that can reduce haze-induced visual deterioration without depending on the inversion of a physical model of haze generation while maintaining the essential assumptions of model. The suggested approach eliminates the necessity for depth estimation in the scene, as well as time-consuming depth map refining operations. A series of gamma-correction processes are used to artificially underexpose the original blurry image for further enhancement. A multi-scale Laplacian blending strategy is used to combine the multiple-exposed images into a haze-free outcome. Combining purposely underexposed images may efficiently eliminate the haze effect, even in difficult scenarios when other existing image dehazing approaches fail to yield excellent results. More advanced approaches might be investigated to increase performance and to explore the alternative possibilities.

The research in [9] designed a newly constructed SAMEER–TU dataset with relevant ground truth information that includes 5390 images recorded in foggy as well as clear conditions. This research also outlines a technique for improving the clarity of cloudy images. A contrast enhancement technique is employed by using luminance weight map, and chromatic weight map followed by multi-scale fusion to improve the visibility of visual impaired images in thick foggy conditions. A qualitative assessment evaluation has been done to validate the robustness of the proposed technique using various evaluation parameters. The proposed approach operates well for dense fog impaired visual images. The proposed technique does not work efficiently when images are acquired in dense fog with extremely low light.

Realistic Single Image Dehazing (RESIDE) has been used by the authors in [10] and is a large-scale benchmark used for evaluation of existing single image dehazing algorithms for artificial and real-world hazy images. RESIDE features a variety of data sources and image details that are organized into five subcategories, each of which serves a particular training purpose. A wide range of criteria for evaluating dehazing algorithms, including full-reference metrics, no-reference metrics, subjective assessment, and the innovative task-driven evaluation is novel to this technique. To evaluate the dehazing outcomes no-reference metrics and human subjective evaluations are employed in addition to PSNR and SSIM. Technique needs development no-reference metrics for evaluating dehazing results that are more closely linked with human perception.

In [11] author presented a highly effective approach for eliminating both uniform and diverse fog from an image by utilizing the dark channel prior (DCP) and guided filter. The varying thickness of fog across different images has been leveraged to analyze and enhance the quality of the dark channel prior image. Precise selection of dark channel prior kernel parameters minimizes the transfer of fog from the input foggy image to the fog-free image, thereby reducing the halo effect around object edges in the final image. Additionally, employing a guided filter to preserve object edges in the image proves to be a rapid and cost-effective approach for generating a fog-free image.

1.2. Survey Table

Table 1. Literature Survey

Author	Proposed scheme	Advantages	Limitations
Ivana Shopovska ,et. al.[2]	A Convolutional Neural Network is trained utilizing image features from various scenarios to understand the existence of people in various modalities and to provide robust findings that can be applied in real-world framework.	Outperforms other conventional methods by a wide margin.	Non-Multi-scale generative network and require a strong content modelling.
Yu Liu, Xun Chen,et.al.[3]	A Siamese Convolutional Neural Network is used in particular to create a weight map that combines the pixel activity information from two source images	Combines activity level analysis and weight assignment that conventional fusion methods encounter.	Network has Architectural complexity.
Yu Han, Yunze Cai, et.al.[4]	A multi-resolution image fusion measure based on Visual Information Fidelity (VIF) is proposed to objectively quantify fusion performance.	High performance for image quality prediction.	Has a scope for improvement in time and computational capability.
B. K. Shreyamsha Kumar[5]	The fusion of input images using average of the weights generated from the detail images retrieved from the source images using Cross Bilateral Filter (CBF)	Detailed images are extracted by computing weights, which makes the algorithm easy to implement.	There is scope for future improvement in bulking artifacts.
Gaofeng MENG, Ying WANG, Jiangyong DUAN, et.al. [6]	The elimination of hazes from a single input image, an efficient regularization approach is being employed This technique has numerous benefits apart from exploration of the transmission function	Has efficacy and efficiency demonstrated by experimental results on a range of hazy images.	A scope of improvement by using a tighter radiance envelop to offer a more precise limitation on the transmissions.

Bolun Cai, Xiangmin Xu, et.al.[7]	Dehaze Net, a trainable end-to-end system for medium transmission estimation is used. Dehaze Net analyses a hazy image and produces a medium transmission map, which is then utilized to recover a haze-free image using an atmospheric scattering model.	Proposed algorithm and pre-existing techniques to attain the results as a dehazed image.	The atmospheric scattering model and transmission map, the expense of computation and memory consumption increases. Hence reducing the processing speed.
Adrian Galdran[8]	A novel image dehazing approach is used that can reduce haze-induced visual deterioration without depending on the inversion of a physical model of haze generation while maintaining the essential assumptions of model.	Extracts more saturated sections from artificially under-exposed variants of an image.	More advanced approaches might be investigated to increase the performance and to explore the alternative possibilities.
Tannistha Pal, Mrinal Kanti Bhowmik, et.al.[9]	A contrast enhancement technique is employed by using luminance weight map, and chromatic weight map followed by multi-scale fusion to improve the visibility of visual impaired images in thick foggy conditions.	The proposed approach operates well for dense fog impaired visual images.	Does not work efficiently when images are acquired in dense fog with extremely low light.
Boyi Li, Wenqi Ren,et.al.[10]	Realistic Single Image Dehazing (RESIDE) is a large-scale benchmark used for evaluation existing single image dehazing algorithms using both synthetic and real-world hazy images.	Evaluate the dehazing outcomes no-reference metrics and human subjective evaluations are employed in addition to PSNR and SSIM.	Technique needs development no-reference metrics for evaluating dehazing results that are more closely linked with human perception.
Pallawi, Natarajan, V.[11]	Efficient method to remove both consistent and varied fog from an image through the application of the dark channel prior (DCP) and guided filter.	Preserves the edges of an image Cost effective and fast algorithm	artifact generation in defogged Image and sky-region over-saturation.

1.3. Comparative Analysis of different Image Defogging Algorithm:

Some of the methods used in [12][13][14] have been tested over foggy Image database and the performance has been measured by means of evaluation parameters. The results have been later on compared for qualitative and quantitative appraisal. For the simulation purpose, HP Zbook with 1.65 GHz Intel Core i5 with 16GB memory has been used and the algorithm has been tested over four different images [15]. It has been depicted from the graph presented in Fig. 3 that the technique presented in [14] outperforms the algorithms designed in [12] and [13] in terms of SSIM and PSNR.

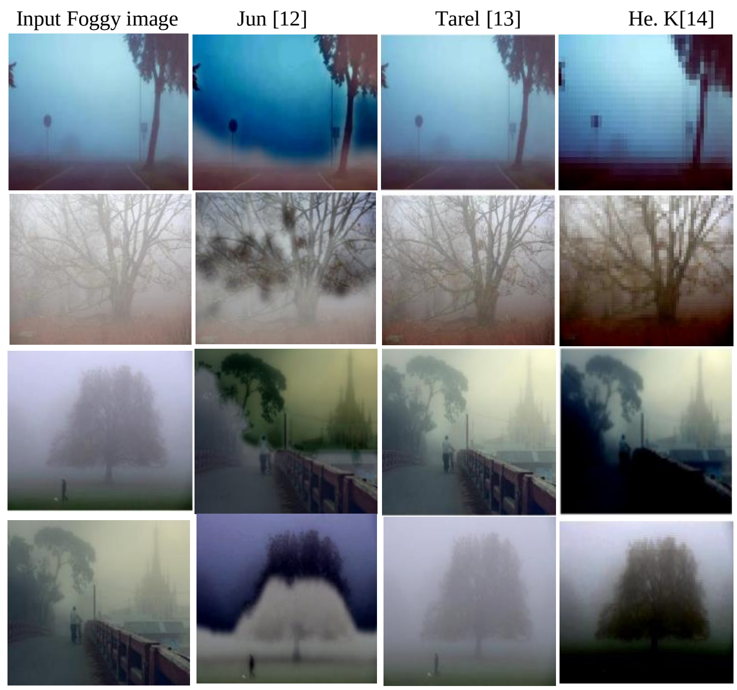

Fig. 2. Image Defogged by techniques presented in [12],[13],[14]. (Database Courtesy [15])

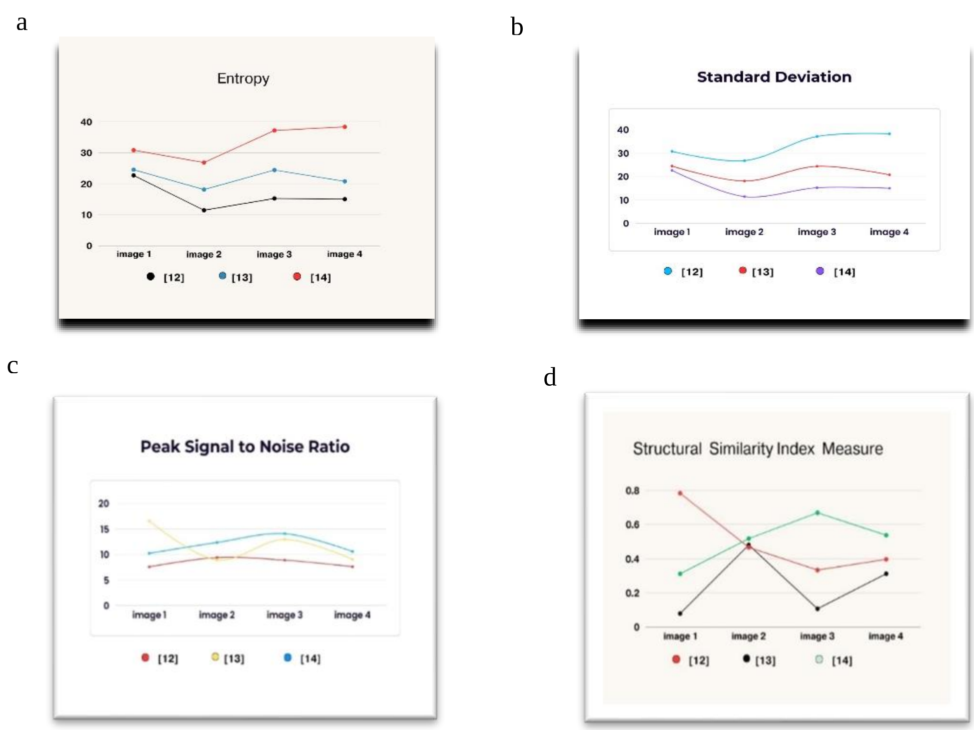

Fig. 3. Graphs depicting the variation of Entropy (a), Standard Deviation (b), PSNR (c) and SSIM(d) for different Images using Techniques presented in [12], [13] and [14]

1.4 Conclusion and Future Enhancement

Image quality has always been a major concern while defogging the images for visibility improvement In this paper various approaches and techniques that were introduced in the past, for the purpose of increasing the performance of image defogging algorithm and hence to enhance the visibility of the scene are discussed. Since infrared sensors can collect thermal information of a scene, the widespread use of infrared imaging today provides an efficient solution in image defogging techniques. Infrared and visible image fusion will try to combine the features of two imaging modalities to create a composite image with clearly extracted thermal subjects and perceptual backgrounds. The Deep Learning approach, being a remarkably powerful tool for solving complex problems, can also be used with fusion strategy so that the quality of the recovered image can be increased. The other alternative to increase the quality further is to use Deep Q-learning Algorithm to make conventional Deep Artificial Neural Networks more efficient. Such Intelligent techniques can also be combined with other computer vision techniques for further increase in efficiency and decrease in computational complexity.

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