Edge-Preserving Decomposition-Based Image Haze Removal – A Survey

Zainab Khan[1], Dr. Anjali Ashish Potnis[2]

[1]*M.Tech. Scholar, Dept. of Electrical & Electronics Engineering, NITTTR, Bhopal, zainabkhan11@yahoo.com, India;*

[2]*Assistant Prof., Dept. of Electrical & Electronics Engineering, NITTTR, Bhopal, apotnis@nitttrbpl.ac.in, India;*

Abstract *–This paper presents a review on edge-preserving decomposition based image haze removal. When the background has dust particles or hazes its image quality and color is degraded. It is well-known that local filtering-based edge preserving smoothing method suffers from halo artifacts. In this paper a survey of many different methods for haze removal just like Laplacian-based visibility restoration approach, edge-preserving decomposition technique, improved image dehazing method, adaptive single image dehazing method and Color Attenuation Prior method has been done.*

Keywords*: Edge-preserving smoothing, weighted guided image filter, edge-aware weighting, detail enhancement, haze removal, exposure fusion.*

I. Introduction

Many applications in computer vision and computer graphics engages image filtering to restrain and/or remove content in images. Plain linear translation-invariant filters with explicit kernels, like mean, Gaussian, Laplacian, and Sobel filters, have been broadly used in image restoration, sharpening/blurring, feature extraction, edge detection etc. Alternatively, LTI filters are capable of implicitly performing by solving a Poisson Equation same as in high dynamic range (HDR) compression, image matting, image stitching, and gradient domain manipulation. The filtering kernels are absolutely defined by the inverse of a homogenous Laplacian matrix. The LTI filtering kernels are spatially independent and invariant of image content. But usually one may desire to consider added information from a known guidance image. The weighted least squares filter utilizes the filtering input (as an alternative of intermediate results, as in) as the guidance, and optimizes a quadratic function, which is the same to anisotropic diffusion with a nontrivial stable state. The guidance image is able to be another image besides the filtering input in several applications. For example, in colorization the chrominance channels be supposed to not bleed across luminance edges; in image matting the alpha not shiny should capture the thin structures in a combined image; in haze removal the Depth layer should be consistent with the outlook. In these cases, we look upon the chrominance/alpha/depth layers as the image to be filtered, and the composite /luminance/scene as the guidance image, correspondingly. The filtering process in and is attained by optimizing a quadratic cost function weighted by the guidance image. The result is identified by solving a large sparse matrix which only depends on the guide. This inhomogeneous matrix implicitly describes a translation-variant filtering kernel. While these optimization based approach frequently defer state-of-the-art class, it comes with the price of costly computational time. One more way to take benefit of the guidance image is to openly build it into filter kernels. The two-sided filter, independently wished-for in, and later indiscriminate in, is the most accepted one of like explicit filters. Its output at a pixel is a weighted average of the in close proximity pixels, where the weights depend on the color /intensity similarities in the guidance image.

JY Sim[4] The guidance image itself can be the filter input or another image. The two-sided filter can smooth small fluctuations and while preserving edges. Though this filter is effective in various situations, it may have unnecessary gradient reversal artifacts near edges. The speedy execution of the bilateral filter is also a challenging problem. Latest techniques rely on quantization process to accelerate but may sacrifice accuracy.
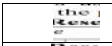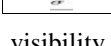
In the paper, B. Y. Zhang [7] proposed a novel precise image filter called guided filter. The filtering output is nearby a linear transform of the guidance image. On one side, the guided filter has fine edge-preserving smoothing property like the bilateral filter, but it does not experience from the gradient reversal artifacts. On the other side, the guided filter is capable to be used beyond smoothing: With the help of the guidance image, it can create the filtering output more structured and less smoothed as compared to the input. In this B. Y. Zhang make obvious

that the guided filter performs extremely well in a great range of applications, including image smoothing and enhancement.

II.   Literature survey

Shih-Chia Huang et al. [1] "An Advanced Single-Image Visibility Restoration Algorithm for Real-World Hazy Scenes" Images captured throughout sandstorm conditions often feature degraded visibility and undesirable color cast effects. In such situations, traditional visibility restoration approaches typically cannot adequately restore pictures because of poor estimation of haze thickness and also the persistence of color cast issues. During this paper, Shih-Chia Huang present a unique Laplacian-based visibility restoration approach to effectively solve inadequate haze thickness estimation and alleviate color cast issues. By doing therefore, a high-quality image with clear visibility and vivid color will be generated. Experimental results via qualitative and quantitative evaluations demonstrate that the planned technique will dramatically improve pictures captured throughout inclement weather and produce results superior to those of different progressive ways. During this paper, Shih-Chia Huang presented a unique Laplacian-based visibility restoration approach for restoration of degraded pictures captured throughout inclement climate, like fog and sandstorms. The planned technique is based on the Laplacian distribution model and options a combination of the planned HTE module alongside the planned IVR module to adequately remove haze formation and recover vivid scene color a picture. Laplacian-based gamma correction is used throughout the planned HTE module to refine an insufficient transmission map and therefore accomplish effective estimation of haze thickness, once that the refined transmission map is used to restore the visibility of a degraded image via the planned IVR module.

Research findings

the Rese e	1.95
Rese e	1.95
r	2.01
r	2.01
r σ	0.00
r σ	0.00

$\bar{r}$ = average visibility enhancement obtained by the restoration algorithm

$\dagger$ = percentage of pixels which becomes completely black or white after restoration.

e = the rate of visible edge restoration in the haze-free image

Zhengguo Li et al. [2] "Edge-Preserving Decomposition-Based Single Image Haze Removal" proposed a simple single image haze removal algorithm by introducing an edge-preserving decomposition technique to estimate the transmission map for a haze image. Experimental results demonstrate that the proposed algorithm is applicable to haze images, underwater images, and normal images without haze. The proposed algorithm is a new frame work for single image haze removal which is from the Koschmiedars law without using any prior. It also introduces a new application for existing edge-preserving smoothing techniques. It should be pointed out that the proposed algorithm has its own limitation. Particularly, the estimated haze degree affects the performance of the proposed algorithm. It is interesting to design a more sophisticated method to detect the haze degree of a haze image rather than using the histogram of a haze image to estimate the haze degree. Another interesting problem is to extend the proposed haze removal algorithm to remove haze from a video sequence.

Research findings

	Image 1	Image2	Image3	Image 4
Running times (s)	1.49	7.93	18.96	12.61

Bin Xie et al. [3] "Improved Single Image Dehazing Using Dark Channel Prior and Multi-Scale Retinex" In this paper, Bin Xie proposed an improved image dehazing algorithmic rule using dark channel previous and Multi-Scale Retinex. Main improvement lies in automatic and fast acquisition of transmission map of the scene. We tend to implement the Multi-scale Retinex algorithmic rule on the luminosity element in YCbCr space; get a pseudo transmission map whose operate is similar to the transmission map in original approach. Combining with the haze image model and also the dark channel previous, we will recover a top quality haze-free image. Compared with the first methodology, our algorithmic rule has 2 main advantages: (i) no user interaction is required, and (ii) restoring the image a lot of faster whereas maintaining comparable dehazing performance. During this paper, Bin Xie planned an improved image dehazing algorithmic rule using dark channel previous and Multi-Scale Retinex. Bin Xie implement the MSR algorithmic rule on the luminosity element in YCbCr color space, use an application-based parameter C to regulate the MSR result, and finally use a median filter on the adjusted luminosity element to get a pseudo transmission map whose operate is similar to the transmission map in original approach. The planned methodology will be used in pre-processing stage in several outside systems, like surveillance, topographic survey, intelligent vehicles, etc. In this paper work additionally shares the common limitation of most image dehazing ways - the haze imaging model could also be invalid and it would be a coincidence that our MSR-based process get the similar variety of transmission map. Bin Xie will additional investigate whether or not there's a theoretical relationship between MSR and also the transmission map. Bin Xie additionally will investigate image dehazing methodology supported another lot of advanced models within the future.

Research findings

	Image 1	Image 2	Image 3
Time(s)	4.2340	6.0470	12.1400
e	1.47	0.92	1.78
$\bar{r}$	1.40	1.38	1.37
	0.92	0.25	0.29

Jin-Hwan Kim et al. [4] "Single Image dehazing based on contrast enhancement" A simple and adaptive single image dehazing algorithmic rule is planned during this work. Based on the observation that a hazy image has low contrast generally, Jin-Hwan Kim decide to restore the first image by enhancing the contrast. First, the planned algorithmic rule estimates the air light during a given hazy image supported the quad-tree subdivision. Then, the planned algorithmic rule estimates the transmission map to maximize the contrast of the output image. To measure the contrast, Jin-Hwan Kim developed a value perform, that consists of a typical deviation term and a histogram uniformness term. Experimental results demonstrate that the planned algorithmic rule will remove haze with efficiency and reconstruct one detail in original scenes clearly. Jin-Hwan Kim planned an easy adaptive dehazing algorithmic rule using a single image that relies on contrast improvement. The planned algorithmic rule initial estimates the air light during a given hazy image supported the quad-tree subdivision. Then, the planned algorithmic rule estimates the optimal transmission to maximize the contrast. To measure the contrast, we tend to Jin-Hwan Kim developed the price function that consists of the quality deviation term and also the histogram uniformity term. Moreover, Jin-Hwan Kim extends the planned algorithmic rule to estimate a space-varying transmission map to dehaze a picture with a com-plicate depth structure additional faithfully.

The proposed algorithm takes about $20 \sim 30$ seconds to dehaze a 600×400 image, while the Tan's algorithm, the Oakley and Bu's algorithm, and the He et al.'s algorithm take about 300, 15, and 60 seconds, respectively.

Qingsong Zhu et. al. [5] "A Fast Single Image Haze Removal Algorithm Using Color Attenuation Prior" Single image haze removal has been a difficult drawback because of its ill-posed nature. During this paper, Qingsong Zhu proposed an easy however powerful color attenuation previous for haze removal from one input hazy image. By making a linear model for modeling the scene depth of the hazy image under this novel previous and learning the parameters of the model with a supervised learning methodology, the depth info may be well recovered. With the depth map of the hazy image, we will simply estimate the transmission and restore the scene radiance via the atmospherically scattering model, and therefore effectively remove the haze from one image. Experimental results show that the planned approach outperforms state-of-the-art haze removal algorithms in terms of each efficiency and also the dehazing impact. During this paper, Qingsong Zhu got planned novel linear color attenuation previous, supported the difference between the brightness and also the saturation of the pixels among the hazy image. By making a linear model for the scene depth of the hazy image with this easy however powerful previous and learning the parameters of the model using a supervised learning methodology, the depth data may be well recovered. By means that of the depth map obtained by the planned methodology, the scene radiance of the hazy image may be recovered simply. Experimental results show that the planned approach achieves dramatically high efficiency and outstanding dehazing effects additionally.

Research findings

Image Resolution	Time Consumption
441 x 450	1.420s
600 x 450	2.219s
1024 x 768	4.278s
1536 x 1024	9.636s
1803 x 1080	12.314s

Pierre Charbonnier et. al. [6] "Deterministic Edge-Preserving Regularization in Computed Imaging" Many image processing problems are ill posed and must be regularized. Usually, a roughness penalty is imposed on the solution. The difficulty is to avoid the smoothing of edges, which are very important attributes of the image. In this paper, Pierre Charbonnier first gives conditions for the design of such an edge-preserving regularization. Under these conditions, Pierre Charbonnier shows that it is possible to introduce an auxiliary variable whose role is twofold. First, it marks the discontinuities and ensures their preservation from smoothing. Second, it makes the criterion half-quadratic. The optimization is then easier. Pierre Charbonnier proposed a deterministic strategy, based on alternate minimizations on the image and the auxiliary variable. This leads to the definition of an original reconstruction algorithm, called ARTUR. Some theoretical properties of ARTUR are discussed. Experimental results illustrate the behavior of the algorithm. These results are shown in the field of tomography, but this method can be applied in a large number of applications in image processing. In this paper, Pierre Charbonnier considered the problem of edgepreserving Regularization in computed imaging. Pierre Charbonnier first aim was to give a unified answer to the question, "What properties must a potential function (or its derivative) satisfy to ensure the preservation of edges?" Pierre Charbonnier proposed a heuristically study of the first-order necessary conditions which led us to propose three conditions for edge preservation.

III.   Method

In the paper classification of the edge-preserving filtering method. In this categorize them as implicit/explicit weighted-average filters and non average ones.

Explicit Weighted-Average Filters

The two-sided filter is perhaps the simplest and most instinctive one among precise weighted-average filters. It computes the filtering output at each pixel as the average of adjacent pixels, weighted by the Gaussian of both intensity and spatial distance. The bilateral filter smooths the image whereas preserving edges. It has been broadly used in noise reduction, HDR compression, multi scale detail decay, and image abstraction. It is generalized to the joint bilateral filter in, where the weights are computed from one more guidance image moderately than the filtering input. The joint bilateral filter is particularly preferential when the image to be filtered is not dependable to provide edge information, e.g., when it is very loud or is an in-between result, such as in flash/no-flash de noising, image up sampling, image de-convolution, stereo matching, etc. The bilateral filter has limits despite its attractiveness. It has been become aware of in that the bilateral filter may undergo from "gradient reversal" artifacts. The cause is that when a pixel has few similar pixels around it, the Gaussian is the efficiency .Abrute-force implementation is O (Nr2) time with kernel radius r. Durand and Dorsey propose a piece-wise linear representation and facilitate FFT-based filtering. Paris and Durand formulate the gray-scale bilateral filter as a 3D filter in a space-range domain, and down sample this area to speed up if the Nyquist condition is approximately true.
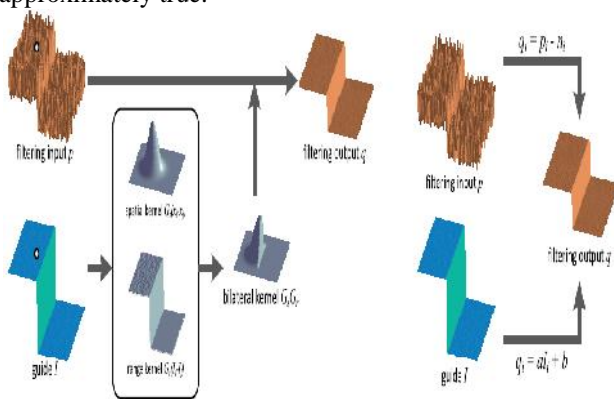

Fig. 1. Illustrations of the bilateral filtering process (left) and the guided filtering process (right).

Implicit Weighted-Average Filters
A string of approach optimizes a quadratic cost function and solves a linear system, which is equivalent to implicitly filter a figure by an inverse matrix. In image segmentation and colorization, the affinities of this matrix are Gaussian functions of the shade similarity. In image matting, a matting Laplacian matrix is designed to enforce the alpha matte as a confined linear transform of the image colors. This matrix is also applied in haze removal. The weighted least squares filter in adjust the matrix resemblance according to the image gradients and produces halo-free edge-preserving smoothing. Although these optimization-based approach often generate high quality results, solving the linear arrangement is prolonged. Direct solution like Gaussian Elimination is not practical due to the memory-demanding "filled in" predicament. Iterative solvers like the Jacobi method, Successive Over-Relaxation (SOR), and Conjugate Gradients are too slow to converge. Though carefully designed pre-conditioners greatly reduce the iteration number, the computational cost is still high. Empirically, the implicit weighted-average filters take at least a few seconds to progression a single megapixel picture either by pre-conditioning or by multigrid. B.Y.Zhang[7]
It has been observed that these inherent filters are very much related to the explicit ones. The bilateral filter is one Jacobi iteration in solution of the Gaussian affinity matrix. The Hierarchical Local Adaptive Preconditioners and the Edge-Avoiding Wavelets are constructed in an analogous mode. In this paper, we explain that the guided filter is closely related to the matting Laplacian matrix.

Non average Filters
Edge-preserving filter can also be attained by non average filters. The median filter is a well-known edge-aware operator, and is an exceptional case of narrow histogram filters. Histogram filters have O (N) time implementations in a way as the bilateral grid. The Total-Variation (TV) filter optimizes an L1-regularized cost function, and are shown equivalent to iterative median filtering. The L1 rate function may also be optimized by means of half-quadratic split, alternating between a quadratic model and spongy contraction (thresholding). In recent times, Paris et al. proposed manipulating the coefficients of the Laplacian Pyramid in the region of every pixel for edge-aware filtering. Xu et al. Propose optimizing an L0-fixed cost function favoring piecewise steady solution. The non average filters are often computationally expensive. Pierre Charbonnier[6.]

IV.   Conclusion

The latest proposed haze removal techniques like Edge preserving decomposition method and many different methods for haze removal like Laplacian-based visibility restoration approach[1], edge-preserving decomposition technique[2], improved image dehazing method, adaptive single image dehazing method and Color Attenuation Prior[6] method has been reviewed.
In this paper classification of the edge-preserving filtering method has been done. Under the categories implicit/explicit weighted-average filters and non average ones. In explicit image filtering the filtering output at each pixel is computed as the average of adjacent pixels, weighted by the Gaussian of both intensity and spatial distance. In explicit image filtering

the bilateral filtering process has been shown in left half of fig.1 and the guided filtering process has been shown in right half of fig.1. In implicit weighted-average filters a string of approach optimizes a quadratic cost function and solves a linear system, which is equivalent to implicitly filter a figure by an inverse matrix. Non average Filters is Edge-preserving filter which can also be attained by non average filters. The median filter is a well-known edge-aware operator, and is an exceptional case of narrow histogram filters.

By surveying all the previous methods for haze removal the results obtained by Shih-Chia Huang et al. [1] "An Advanced Single-Image Visibility Restoration Algorithm for Real-World Hazy Scenes" for the parameters $e, \dagger$ and $\bar{r}$ were the best.

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