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Rain Removal in Digital Images using Guided Filter

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ABSTRACT

Image rain water streak removal is an important problem in image processing. It is a kind of noise but with edge like pattern. Therefore, in rain streak removal edge detection and their filtering is also important. However, the challenging task is to differentiate between actual edges and rain streak edges. Therefore edge enhancement is applied to differentiate rain and non-rain edges. Finally, with the use of guided filter image is smoothen and then rain streaks are removed. The main aim of image smoothing is to remove noise, blur, and haze and halo artifacts which occur in edge of a digital image. Image smoothing technique which preserves the edge details as well as improve in visualizing the quality of an image. Noise is any undesired signal that contaminates the image, which is the result of errors in the image acquisition process that result in pixel values. In this work, further enhancements in recently proposed methods are suggested to further enhance the results. In this work we have modified our objective function and newly considered objective function consider both mean and variance.

Keywords: *Rain Streak removal, edge detection, Guided filtering*

1. INTRODUCTION

Digital Image Processing and Computer Vision play important roles in Application Areas like 1. Intelligent Transportation Systems- used in automatic number plate recognition and traffic sign recognition 2. Remote Sensing- The sensors capture the pictures of the earth's surface in remote sensing satellites or multi-spectral scanner which is mounted o an aircraft 3. Biomedical Imaging Techniques- for medical diagnosis, Different types of imaging tools such as X-ray, Ultrasound, and Computer aided Tomography (CT) are used.
The purpose of image processing is divided into 5 groups like 1. Visualization - observe the objects that are not visible 2. Image sharpening and restoration - to create a better image 3. Image retrieval - seek for the image of interest 4. Measurement of pattern - measures various objects in an image 5. Image recognition - distinguish the objects in an image.
The main aim of image smoothing is to remove noise, blur, and haze and halo artifacts which occur in edge of a digital image. Image smoothing technique which preserves the edge details as well as improve in visualizing the quality of an image. Noise is any undesired signal that contaminates the image, which is the result of errors in the image acquisition process that result in pixel values. Noise can be caused in images by random fluctuations in the image signals. Blurring of an image, which reduce the edge content and makes the transition from one color to the other very smoothly. An image looks sharper or more detailed if we are able to perceive all the objects and their shapes correctly in it. For example an image with face looks clear then we can able to identify eyes, nose, ears etc. in a very clear manner. This shape of an object is due to its edge. Haze often occurs when dust and smoke particles accumulate in relatively dry air. When weather conditions block the dispersal of smoke and other pollutants they concentrate and form a usually low-hanging shroud that impairs visibility and may become a respiratory health threat. Industrial pollution can result in dense haze, which is known as smog. Haze is traditionally an atmospheric phenomenon where dust, smoke, fog, sand, snow and other dry particles obscure the clarity of the sky. The clarity of the sky is not visible while capturing an image which is due to haze. Median filter based on fuzzy rules and its application to image restoration is the most used method but it is not working efficiently when its noise rate is above 0.5[1]. An adaptive fuzzy multilevel filter used in the heuristic rules for improving the performance of multilevel median filter[2].A fuzzy operator for the enhancement of blurred and noisy image uses heuristic knowledge to build fuzzy operators for smoothing, sharpening and edge detection but it is not efficiently working in brightness[3].A powerful robust approach to image enhancement based on fuzzy logic approach is introduced which removes impulse noise as well as it preserve edge well[4].So a good smoothing algorithm should be able to deal with different types of noise, halo artifacts. Image smoothing often causes blur and offsets of the edge. It’s very important about the edge information for image analysis and interpretation [5].

2. NOTABLE RESERACH

At present, the techniques that are used to eliminate rain or snow could be grouped into two classes. These two classes are 1- for videos, 2- for single images. Gary and Nayar, for videos, made a correlation model capturing the dynamics of rain and a physics-based motion blur model stating the photometry of rain [6, 7]. Zhang et al. introduced a detection method combining temporal with chromatic properties of rain [8]. Barnum et al. modeled the rain or snow steaks with the help of a blurred Gaussian model, rain and snow can be detected and eliminated based on the statistical information in frequency space with a number of frames [8, 9]. Bossu et al. proposed a rain removal via foreground separation, selection rules and detecting by HOS [10]. These methods well remove rain or snow in videos. However, aforementioned methods are not suitable to the case of single image since there is no reference temporal information. As a result, the tasks become more challenging in the case of single image. For single-image-based approach, Kang et al. proposed a rain removal method by image decomposition, in which the rain components of single image could be removed via performing dictionary learning and sparse coding [11]. However, the method cannot remove the non-orientation snowflakes. Xu et al. proposed a method using guided filter to remove rain or snow [12]. Zheng et al. proposed a new method to remove rain or snow through using guided filter to get the smooth image [13]. Yi-Lei Chen and Chiou-Ting Hsu proposed a novel low-rank appearance model for removing rain streaks [14]. Duan-Yu Chen et al. proposed a visual depth guided color image rain streaks removal method using sparse coding [15]. After removing rain streaks and snowflakes, objects in the image can be seen clearly. On the other hand, the rain streaks or snowflakes in single image can be considered as the image noise. Some common denoising methods are available for rain or snow removal. For example, the bilateral filter [16] is an edge-preserving smoothing filter which considers the influence of distant pixel and their variance. The non-local means algorithm [17] is a popular image denoising method which is based on a non-local averaging of all pixels in an image. The guided filter, proposed in [18] and [19], transfers the structures of guidance image to the filtering output, and this filter has the edge-preserving smoothing property. Even these denoising methods can directly apply for single image rain or snow removal, the effects are poor and the results are always artificially blurred. Whatsoever, for many single image rain removal methods, these denoising methods can be a good pre-processing, such as [15, 11, 12, 13] and the proposed method. In this work, a guided L_0 smoothing filter is designed based on the L_0 gradient minimization [20]. Firstly, a coarse but nearly rain-free or snow-free guidance image is obtained by adopting the traditional guided filter [18, 19]. Then the proposed guided L_0 smoothing filter is designed to remove rain or snow. The structure of the paper is given as follows: the background information is introduced in Section 2, followed by the design of the guided L_0 smoothing filter in Section 3.

3. Rain Removal Process

We use outdoor vision system for a number of purposes like navigation, surveillance etc. Although, in the situation of bad weather, generally unsatisfied human seeing, result in problems in image processing and degrades the performance of vision algorithms like feature detection, stereo correspondence, tracking, segmentation, object recognition and so on. On the basis of the kind of visual effects, bad weather conditions can be classified into steady (haze, fog and mist) or dynamic (rain, snow, hail) [21]. Rain or snow could be very common factors which are responsible for decreasing visibility. An image captured in falling rain or snow is covered with lots of bright streaks or white spots to confuse human vision. In this chapter, a rain streak removal process is detailed, and modification is suggested to further enhance the results.

3.1 Background

This section presents the fundamental overview of various concepts associated with rain and snow [21].

3.1.1 The physical property of rain or snow

Generally, the size of raindrop is 0.1-3.5mm. Since raindrop usually fall quickly, they are imaged as rain steaks in the image. And only a few pixels are occupied with rain steaks, and snowflakes are similar to rain steaks.

We have three observations on regular rain streaks or snowflakes. The first one is because of the small size and rapid speed; camera is only able to capture raindrop or snowflake as little streaks or spots. The second observation is that the light of raindrop can be refracted, and the snowflake is white and bright in nature, which means the rain streaks or snowflakes are brighter than the background. The third one is the size of rain streaks or snowflakes are small, and they are sparse. The image taken from real-world scenes is usually piecewise smooth. So the degraded background can be restored through the value around the rain streaks or snowflakes.

3.1.2 The mathematical model of rain or snow image

The below given model is generally used to explain the formation of rain or snow image:

$$I_{in} = (1-\alpha) I_b + \alpha I_r, \qquad (0 \le \alpha \le 1), \tag{1}$$

In the above equation, the parameter I_{in} represents the input image while I_b is the clean background image. I_r Represents the rain or snow component and α is the scale parameter. At the moment of $\alpha = 0, I_{in} = I_b$, , the observed image is not influenced by rain or snow. In the process of removing rain or snow, we don't require to deal with this situation.

When $\alpha \ne 0, I_{in} = (1-\alpha) I_b + \alpha I_r$, then $I_{in} > I_b$ .The primary purpose of removing rain or snow is of recovering the background I_b from the observed image I_{in}. This could be said as an ill-posed issue, and some extra prior information is required to make the recovery of the background.

3.1.3 The edge characteristic of rain or snow

On the basis of the relation between the edges pixels and their surrounding pixels, each of the edge can be grouped into three classes (Fig. 1): step edges, ridge edges and valley edges.

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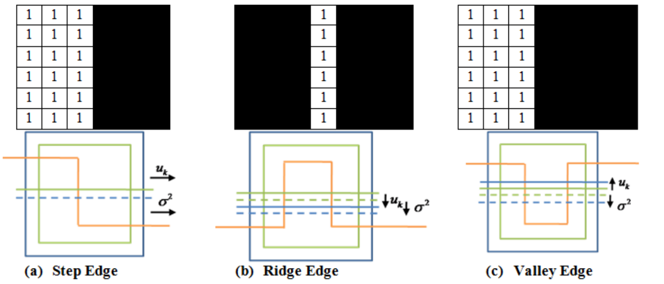

Figure 1 : Edge type representation

In the figure given above, suppose all points of the edge be the center of the corresponding window (the window size is k ∗ k; k = p, p + 1 ······ ; p is the edge's width). We will make the calculation and comparison of the means and variances in the corresponding windows with a specific end goal to recognize three sorts of edges. The mean and variance for step edges nearly stays unaltered regardless of the size of window ends up bigger. Still for ridge edges and valley edges, we will have changes in their means and variances with the increase in the window size. Concretely, when the size of the window grows for ridge edges, the means become smaller and close to their adjacent pixels, and the variances also become smaller and close to zero; while for valley edges the means become lager and close to the adjacent pixels, and the variances also become smaller and close to zero. Comparing with the surrounding pixels, the size of rain steaks or snowflakes is smaller and their values are higher than surrounding pixels. So the ridge edges with limited size are considered as rain streaks or snowflakes, and most of the other edges in the background are step edges or valley edges. Therefore, we can distinguish the rain streaks or snowflakes from the background or background defined by texture in this way.

3.2 The rain-free or snow-free guidance Image

3.2.1 Guided filter

We can define the Guided filter as an edge-safeguarding smoothing filter, which functions admirably close to the edges [43, 44]. We can have the observed image or any other reference image as Guidance image. In addition, the guided filter is a quick and non approximate linear time calculation, whose computational unpredictability is autonomous of the filtering kernel size. Especially, guided filter plans output picture as takes after:

$$I_{out} = \frac{1}{|\omega|} \sum_{k|i \in \omega_k} (a_k I_i + b_k), \qquad (2)$$

In the above equation, ω_k is a window centered at the pixel k, $|\omega|$ is the number of pixels in the window, I is guidance image, a_k and b_k are defined as:

$$a_k = \frac{\frac{1}{|\omega|} \sum_{1 \in \omega_k} I_i p_i - \mu_k \bar{p}_k}{\sigma_k^2 + \varepsilon}, \qquad (3)$$

$$b_k = \bar{p}_k - a_k \mu_k$$

Here the parameters μ_k and σ_k^2 are used to represent the mean and variance of I in ω_k, p is the input image, $\bar{p}_k$ is used to represent the mean of p in ω_k, the parameter ε is a regularization parameter to limit the structural similarity. The greater ε is, the smoother the output will be.

3.2.2 The low frequency part

When the input image is treated as the guidance image $(p = I), a_k = \frac{\sigma_k^2}{\sigma_k^2 + \varepsilon}$ and $b_k = (1 - a_k)\mu_k = \frac{\varepsilon}{\sigma_k^2 + \varepsilon}\mu_k$

and the output image using guided filter is formulated by

$$I_{out} = \frac{1}{|\omega|} \sum_{i \in \omega_k} \left(\frac{\sigma_k^2}{\sigma_k^2 + \varepsilon} I_i + \frac{\varepsilon}{\sigma_k^2 + \varepsilon} \mu_k \right). \qquad (4)$$

The low frequency part of the above discussed three sorts of edges after making use of guided filter will change in a different way. As illustrated in Fig. . .2, we have the below given analysis:

Edges		**Pixel**	**Compare with mean**	**Output after guided filter**
Step edges		I_1	$I_1 > u_k$	$I_{out} \to u_k$
		I_2	$I_2 < u_k$	$I_2 < I_{out} < u_k$
Ridge edges	Small	I_1	$I_2 > u_k$	$I_{out} < u_k$
	Large	I_2	$I_2 > u_k$	$u_k < I_{out} < I_2$
Valley Edges		I_1	$I_2 < u_k$	$I_1 < I_{out} < u_k$

The low frequency section of step edges subsequent to utilizing guided filter is still step edges, yet their ranges turns to be smaller, which implies that the step edges move toward becoming smoother after making use of guided filter (as the step edges in Fig. 2).

In the event of the ridge edges with small size are not influenced by the other edges, their variances are near to 0, at that stage the ridge edges will not appear and tend to the background. While I_i belongs to the ridge edges with large size, it is not easy to make I_{out} be equal to background, therefore the low frequency part of ridge edges with large sizes will remain and become smoothed (as the ridge edges in Fig. 2). The value of low frequency part for valley edges will become larger than the input (as the valley edges in Fig. 2).

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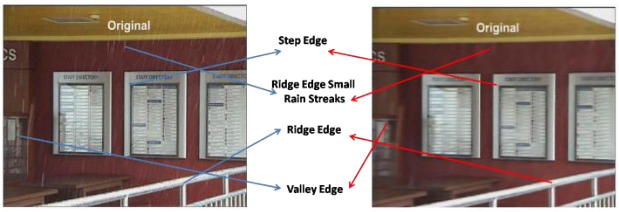

Figure 2: Various types of edges in House image

Therefore, on the basis of the above explanation, it is concluded that the low frequency part that is using guided filter can be identified among the three-kinds of edges, (as shown in Figure 2) i.e., the step edges will be retained, still will turn a bit smoother; the ridge edges with small size will disappear, while the ridge edges with large size will be retained; the pixel values of valley edges will become higher in the low frequency part.

In any case, we can't specifically evacuate rain or snow by this conventional guided filter. As a matter of fact, on the off chance that we see input picture as the guidance image, we can just get an unpleasant outcome. Since the edges in the output are changed by the input image to way to deal with the edges in guidance image and it isn't the original edges in the input picture any longer. The guided filter does not function admirably for this situation.

In any case, guided filter can be a decent pre- processing of rain expulsion technique. The low frequency part is an image just keeping the data of contour of background and without residual the edges due to rain or snow. It can be viewed as a guidance image in the proposed strategy. Utilizing both the guidance image and the original observed image, rain or snow can be evacuated with the help of the guided L_0 smoothing filter.

3.3 Guided L_0 smoothing filter

In this part of the literature, initially we review the theory of L_0 gradient minimization [48] in brief, and make the simple explanation of the corresponding solver. After this, on the basis of the model of L_0 gradient minimization, the guided L0 smoothing filter is introduced. After that, we present its application to remove rain or snow.

In gradient based method we count amplitude changes as

$$c(f) = N\{p \mid |f_p - f_{p-1}| \neq 0\} \tag{5}$$

where p and p - 1 index neighboring samples (or pixels). $|f_p - f_{p-1}|$ is a gradient w.r.t. p in the form of forward difference. $N\{\}$ is the counting operator, outputting the number of p that satisfies $|f_p - f_{p-1}| \neq 0$, that is, the L_0 norm of gradient. $c(f)$ does not count on gradient magnitude, and thus would not be affected if an edge only alters its contrast/

We express the specific objective function as

$$\min_f \sum_p (f_p - g_p)^2 \quad \text{s.t.}, \; c(f) = k \tag{6}$$

$c(f) = k$ indicates that k non-zero gradients exist in the result, and denote the input discrete signal by g and its smoothed result by f.

In practice, k in Eq. (2) may range from tens to thousands, especially in 2D images with different resolutions. To control it, we employ a general form to seek a balance between structure flattening and result similarity with the input, and write it as

$$\min_f \sum_p (f_p - g_p)^2 + \lambda \, c(f) \tag{7}$$

3.3.1 L_0 gradient minimization

With the help of L_0 gradient minimization, the L_0 norm could be directly optimized to have a piecewise steady output image [48]. It is quite useful in sharpening prominent edges through enhancing the steepness of transition at the time of wiping out low-amplitude structures. In this research article, the following minimization problem (8) needs to be solved

$$\min_f \left\| f - f^* \right\|_2^2 + \lambda \left\| \nabla f \right\|_0 \tag{8}$$

In the above equation, f is output, ∇f represent the gradients of f, the parameter f^* is the observed image, and λ is a weight to control the level of detail. The previously used term is for fidelity, the later is to constraint the gradient magnitude of the output.

With the end purpose to overcome the issue of the objective function, auxiliary variable δ is developed to deal with ∇f, therefore (8) could be defined as the following minimization:

$$\min_f \left\| f - f^* \right\|_2^2 + \beta \left\| \delta - \nabla f \right\|_0 + \lambda \left\| \delta \right\|_0 \tag{9}$$

In the above equation, the parameter β *makes the* controls over the similarity between variables δ and ∇f, and the smoothing level is controlled by λ, δ is a vector with two components: δx and δy. Then equation (9) is solved with the help of alternatively minimizing [15] δ and f.

3.3.2 Guided L_0 smoothing filter

Not very long time before Xu et al. introduced L_0 gradient minimization in order to sharpen and maintain prominent edges, in the interim smooth low-amplitude structures in accordance with the observed image [48]. If we talk about this situation (rain or snow removal), we don't plan to keep all the prominent edges aside from ones with low gradients, therefore the pure L_0 gradient minimization technique will fail in the task of rain or snow removal.

Therefore, X. Ding et. al., propose a guided L_0 smoothing filter. It takes benefits of the property of guided filter with L_0 gradient minimization. Dissimilar to the original L_0 gradient minimization, the edges of upgraded result can be protected or smoothed by the rain-free/snow-free guidance image. In particular, the watched picture's edges can be held if the comparing areas of the direction picture is of vast inclination extents, and they will be smoothed if the relating areas are of low angle sizes.

Therefore, X. Ding et. al., call the proposed algorithm to be guided L_0 smoothing filter.

At first, when f^k is known, we optimize the δ^k as (10), where λ must be small to keep all gradients information

$$\min_{\delta^k} \beta^k \left\| \nabla f - \delta^k \right\|_2^2 + \lambda \left\| \delta^k \right\|_0 \quad (k = 1, 2, 3....) \tag{10}$$

We can solve the above equation as

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ITEE Journal
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$$\delta^k = \begin{cases} 0 & \nabla f^k \le \dfrac{\lambda}{\beta} \\ \nabla f^k & others \end{cases} \quad (11)$$

Secondly, when f^k and δ^k are known, we solve f^{k+1} by:

$$\min_{f^{k+1}} \left\| f^{k+1} - f^* \right\|_2^2 + \beta^k \left\| \delta^k - \nabla f^{k+1} \right\|_2^2 \quad (12)$$

Then the expression (12) is equivalent to (13):

$$\begin{cases} \min_{f^{k+1}} \left\| f^{k+1} - f^* \right\|_2^2 + \beta^k \left\| \nabla f^{k+1} - H .* \nabla f^k \right\|_2^2 \\ H = \begin{cases} 0 & \delta^k = 0 \\ 1 & \delta^k \ne 0 \end{cases} \quad (k = 1, 2, 3 \ldots\ldots) \end{cases} \quad (13)$$

Due to the fact that the objective function is quadratic therefore it is a convex optimization issue. Thus, we can apply the least square technique and Fourier transformation to solve it. At that point, the solution of (12) or (13) is:

$$f^{k+1} = ifft\left(\frac{fft(f^*) + \beta\left(fft(\partial_x^T) fft(\delta_x^k) + fft(\partial_x^T) fft(\delta_x^k) \right)}{fft(1) + \beta\left(fft(\partial_x^T) fft(\partial_x) + fft(\partial_y^T) fft(\partial_y) \right)} \right) \quad (14)$$

The parameter fft represent the fast Fourier transform operator and the parameter $ifft$ is used to represent its inverse. ∂x and ∂y implies difference operators in the horizontal and vertical directions, respectively.

At last, when s^k and δ^k are known, we solve s^{k+1} from (15)

$$\begin{cases} \min_{s^{k+1}} \left\| s^{k+1} - s^* \right\|_2^2 + \beta^k \left\| \nabla s^{k+1} - H .* \nabla s^k \right\|_2^2 \\ H = \begin{cases} 0 & \delta^k = 0 \\ 1 & \delta^k \ne 0 \end{cases} \quad (k = 1, 2, 3 \ldots\ldots) \end{cases} \quad (15)$$

The solution of (15) is:

$$s^{k+1} = ifft\left(\frac{fft(s^*) + \beta\left(fft(\partial_x^T) fft(H .* \nabla s_x^k) + fft(\partial_x^T) fft(H .* \nabla s_y^k) \right)}{fft(1) + \beta\left(fft(\partial_x^T) fft(\partial_x) + fft(\partial_y^T) fft(\partial_y) \right)} \right)$$

Algorithm:

Input: observed image s^*, guidance image f^*, parameters λ, β_0, β_{max} ,rate κ

Initialization: $f^1 \leftarrow f^*, s^1 \leftarrow s^*, \beta^1 \leftarrow \beta_0, k \leftarrow 1$,

repeat:

with f^k, solve δ^k for in (8);

with f^k and δ^k, solve for f^{k+1} in (10);

with s^k and δ^k, solve for s^{k+1} in (13);

$\beta \leftarrow \kappa\beta, k{+}{+}$;

Until $\beta_0 > \beta_{max}$

Output: The result of guided L_0 smoothing filter *s*.

3.4 The Ideology of method

The technique is demonstrated in Figure.3. At first, the part with the low frequency of the observed image will be acquired by the conventional guided filter, i.e., we get a blurred guidance image free from rain or snow. Due to the fact that the rain streaks are not big and inadequate to hardly cover the background, and observed image has genuine background information, and the guided L_0 smoothing filter is used to restore the rain-free/snow-free result. The valley edges do not need to be restored due to the reason that they don't belong to rain streaks or snowflakes. So at last, the minimization operation was taken between the observed image and the rain-free or snow-free result to get the final refined result.

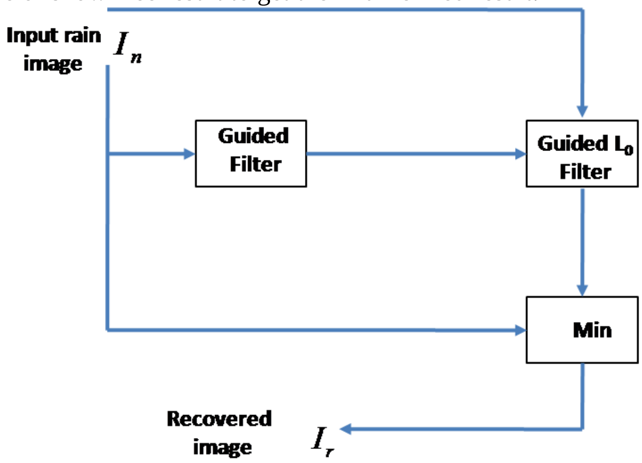

Figure 3: Rain streak removal process

4. Our Proposed Method

In the proposed method we have used both mean

$$\min_f \left[\left\| f - f^* \right\|_2^2 + \lambda \left\| \nabla f \right\|_0 + \beta\sigma^2 \right] \quad (16)$$

Under the constrains

$$E(f) - E(f^*) < \varepsilon \quad (17)$$

Where $,\mu = E(f)$ is the mean of initial image, and $\sigma^2 = E[f - E(f)]^2$ is the variance of initial image.

The gradient ∇f is a measure for edge detection and preservation. The gradient of image *f* is defined as

$$\nabla f = \sqrt{\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2}}. \quad (18)$$

Ideally, we want to find $f = f^*$, than σ^2 will be minimum and equals to original image.

Simulation Details and Results

In this process, guided filter is applied three times to recover rain free image. The step by step details are as below:

Step 1: Apply guided filter on input image (I_{in}) smoothening

Step 2: Apply High and low pass processing ($I_{in} = I_{LF} + I_{HF}$)

Step 3: Apply edge enhancing process using Laplacian on low pass image

$$I_{LF}^{new} = I_{LF}^{old} + m I_{LF}^{edge}$$

Step 4: Apply guided filter on high pass image (I_{HF}), while considering I_{new} as guided image to obtain I_{HF2}.

Volume 7, Issue 5
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Step 5: Add image obtained in step 3 and step 4, to obtain recovered image.

$$I_r = I_{HF2} + I_{LF}^{new}$$

Step 6: Obtain clear image using min on image obtained in step 5 and input image.

$$I_{cr} = \min(I_r, I_{in})$$

Step 7: Obtain reference image while considering weightage of image in step 5 and step 6.

$$I_{ref} = \gamma I_{cr} + (1-\gamma) I_r$$

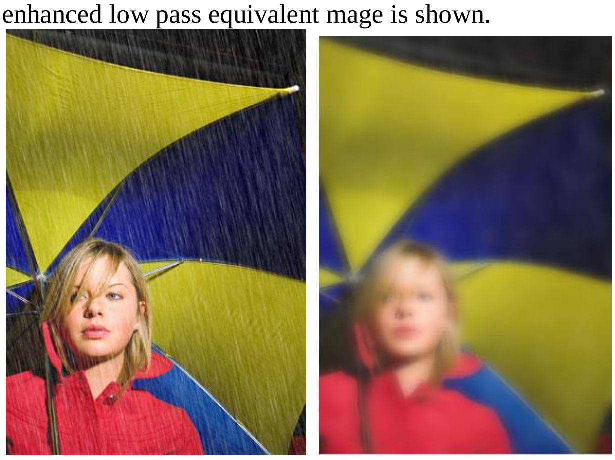
Step 8: Again applying guided filter on obtained image (I_{cr}) in step 6, while considering image in step 7 as reference image (I_{ref}).

Results

To make comparison fairer and easier in the current work same images of 'House' and Woman is considered as in previous work.

Parameters for House Image	**Parameters for Woman Image**
Window size = [3 15]; Guided Filter 1, ε= 0.1; Guided Filter 2, ε= 0.001; Guided Filter 3, ε = 0.0001; difference= 0.2;	Window size = [10 15]; Guided Filter 1, ε= 0.2; Guided Filter 2, ε= 0.01; Guided Filter 3, ε = 0.01; difference = 0.1;

Results for woman image is shown in Figure 4 (a)-(j). In figure 4(a) original image with rain streak is shown. Its low pass equivalent is shown in figure 4(b) and high pass components are shown in figure 4(c). In figure 4(d) edge enhanced low pass equivalent mage is shown.

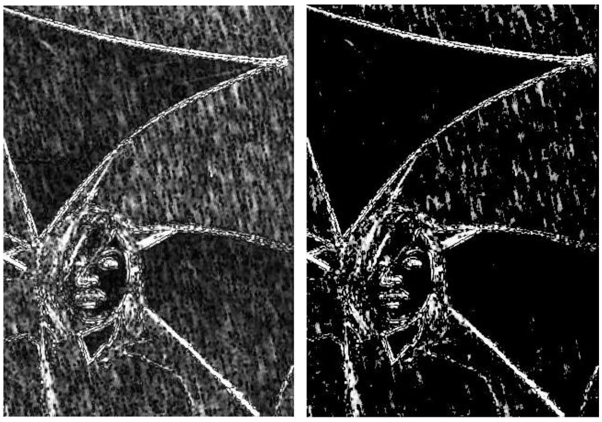


(a) (b)

Figure 4: (a) Input Woman Image (b) LF input image

(c) (d)

Figure 4: (c) HF input image (d) Edge Enhanced LF input image



(e) (f)

Figure 4: (e) The Estimated Rain streak (f) Gradient

(g) (h)

Figure 4: (g) Recovered Image (h) Recovered clear image

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ITEE Journal
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(h) (j)

Figure 4: (i) Result using old method (j) Result using proposed method

In Figure 4 (e) estimated rain streak is shown, and its gradient is shown in Figure 4(f). Recovered image is shown in Figure 4(g), and clear image is show in Figure 4(h). The final image with rain removal is shown in Figure 4(i), and final recovered image with our proposed method is shown in Figure 4(j).

4. Conclusions

Image processing is a hot area of research, as images get corrupted due to noises and blurring etc. In the similar directions images also becomes unclear due to haze, rain and snow etc. In past work rain removal L_0 filter is designed along with use of guided filter. However, while recovering the image variance is allowed to change abruptly, which restricts the quality improvement. To tackle this, in this work variance is also minimized to obtain better quality of recovered image. Finally it has been found that proposed system is more effective than the earlier one. In nut shell following major conclusions are can be made:

1. In image rain streak removal, guided filter plays important role.
2. Edge enhancement process makes rain removal easier.
3. Classifications of edges are also important in image identification.
4. Min operation is important in image enhancement.
5. The minimization of variance also reduces variability in image, and we get better results.
6. The use of multiple guided filters is essential to carry out various stage processing.

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