Single-Image-Based Rain and Snow Removal Using Multi-guided Filter

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Abstract. In this paper, we propose a new rain and snow removal method through using low frequency part of a single image. It is based on a key difference between clear background edges and rain streaks or snowflakes, low frequency part can obviously distinguish the different properties of them. Low frequency part is the non-rain or non-snow component. We modify it as a guidance image, the high frequency part as input image of guided filter, so we get a non-rain or non-snow component of high frequency part and add the low frequency part is the restored image. We further make it more clear based on the properties of clear background edges. Our results show that it has good performance in rain removal and snow removal.

Keywords: rain removal, snow removal, low frequency.

1 Introduction

A photo taken in the rainy day or snowy day is covered with bright streaks (Figure 1). The streaks not only cause a bad human vision, but also significantly degrade effectiveness of any computer vision algorithm, such as object recognition, tracking, retrieving and so on.

Removal of rain or snow has been paid much attention, especially rain removal. Gary and Nayar suggested a correlation model capturing the dynamics of rain and a physics-based motion blur model explaining the photometry of rain [1]. Then they proposed how to modify camera parameters to remove the effects of rain [2]. Zhang proposed a detection method combining temporal and chromatic properties of rain [5]. Barnum thought rain or snow streaks are formulated by a blurred Gaussian model, and rain or snow is detected base on the statistical information in frequency space with different frames. Then rain or snow can be removed or increased [6] [7]. Fu et al proposed a rain removal method via image decomposition, the rain component of single image could be removed via performing dictionary learning and sparse coding [8]. Jing xu proposed a method using guided filter to remove rain streaks or snow streaks[10], and then improved the performance by refining the guidance image [11].

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In this work, a novel method is proposed based on the difference between clear background edges and rain streaks or snow streaks. The method mainly uses the guided filter to remove rain streaks or snowflakes. Section 2 suggests that the rain streaks or snowflakes are different from other textures. In Section 3 we introduce the algorithm of removing the rain streaks or snowflakes. Section 4 shows the experimental results and compares with other methods. The last part is conclusion.

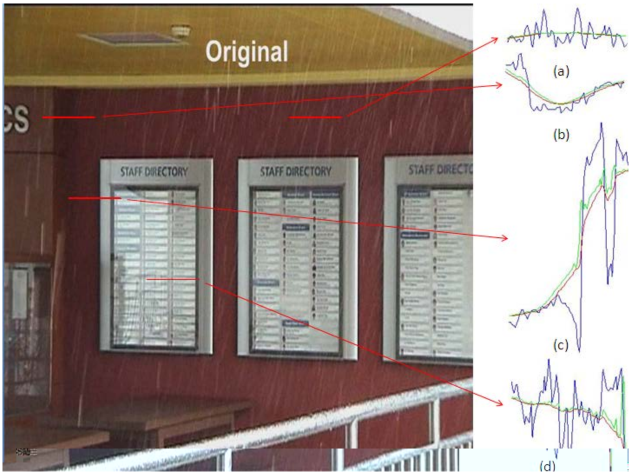


Fig. 1. Intensity profiles along the horizontal indicated by the red line. (a) Blurred rain streaks; (b) The edges with low pixel values; (c) The edges of different adjacency pixel values; (d) The clear background edges like rain. Blue line is pixel values of input image in a partial row to the same scale. The red line is the corresponding low frequency part via guided filter. The green line is the edge enhancement of red line.

2 The Difference between Clear Background Edges and Rain or Snow Streaks

Due to the size and the speed of raindrop or snowflake, they are imaged in form of bright and blurry streaks. The streaks are higher than adjacent pixel values and they will disappear in the low frequency part such as Figure 1(a). Some background edges are lower than adjacent pixel values like Figure 1(b) and they can't be rain or snow streaks. But the values will become higher through using guided filter. Other edges like Figure 1(c), some pixels near to the edges are higher, the others are lower, these edges are retained in low frequency, but become a little smooth, can be recovered through edge enhancement. There exist some textures like rain or snow streaks, which are also higher than adjacent pixel values, but they are clearer than rain or snow streaks, as shown in Figure 1(d). After transforming to low frequency part by appropriate parameters, some of them are likely to become the little textures. And we also enhance them to close to original textures.

2.1 Image Model of Blurred Rain Streaks or Snow Streaks

The commonly used mathematical model of rainy or snowy image, that is, input image can be decomposed into two components: a clean background image and a rain or snow component.

$$I_{in} = I_b + I_r \tag{1}$$

For obviously seeing the different textures of rain or snow and background, firstly, an input image is decomposed into low frequency part and high-frequency part by using guided image filter. The low frequency part is non-rain or non-snow component. All the rain and snow streaks are in the high-frequency part, which also has non-rain or non-snow textures. The opinion above is the same as [8] [12] [13]. So formula (1) can be changed to (2): I_{bl} is the low-frequency part of background. I_{bh} is the high-frequency part of background. I_{rh} denotes the rain or snow in the high-frequency part. I_{in}^{guide} means the transformation of I_{in} by using guided filter.

$$I_{in}{=}I_{bl} + I_{bh} + I_{rh} = I_{in}^{guide}{+}I_{bh} + I_r \tag{2}$$

and (2) can be simplified as (3):

$$I_{in} = I_{LF} + I_{HF} \tag{3}$$

The transformation makes the textures change, which can be showed by the red line in Figure 1. From the Figure 1(a) and Figure 3(b), we see the low frequency part is non-rain part, and contains the edges of the background. So we get a non-rain or non-snow guidance image. By using it we can remove rain and snow. The experiment results prove our idea.

2.2 Guided Filter

Guided filter is an edge-preserving smoothing filter, and has good behavior near the edges [9]. Guidance image can be itself or another reference image. Besides, "the guided filter has a fast and non approximate linear-time algorithm, whose computational complexity is independent of the filtering kernel size". So we choose it to realize our idea. Guided filter formulates output image I_{in}^{guide} is a linear of guidance image I as followed:

$$I_{in}^{guide} = \overline{a_k} I_i + \overline{b_k} \tag{4}$$

where a_k and a_k are defined as:

$$a_k = ((\sum\nolimits_{i\in\omega_k} I_i p_i)/|\omega| - \mu_k \overline{p_k}))/(\sigma_k^2 + \varepsilon) \tag{5}$$

$$b_k = \overline{p_k} - a_k \mu_k \tag{6}$$

3 Rain and Snow Removal

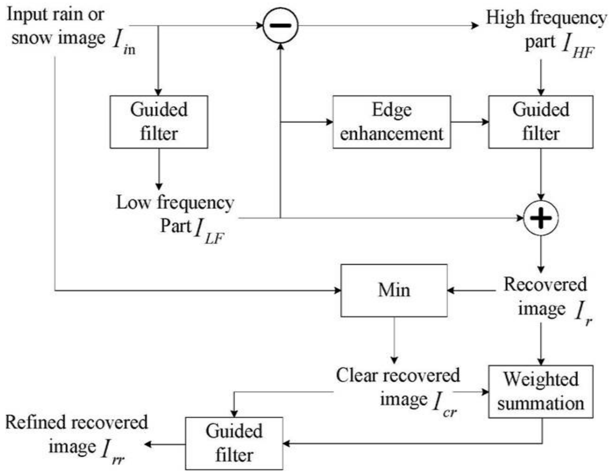


Fig. 2. Block diagram of the proposed removal method

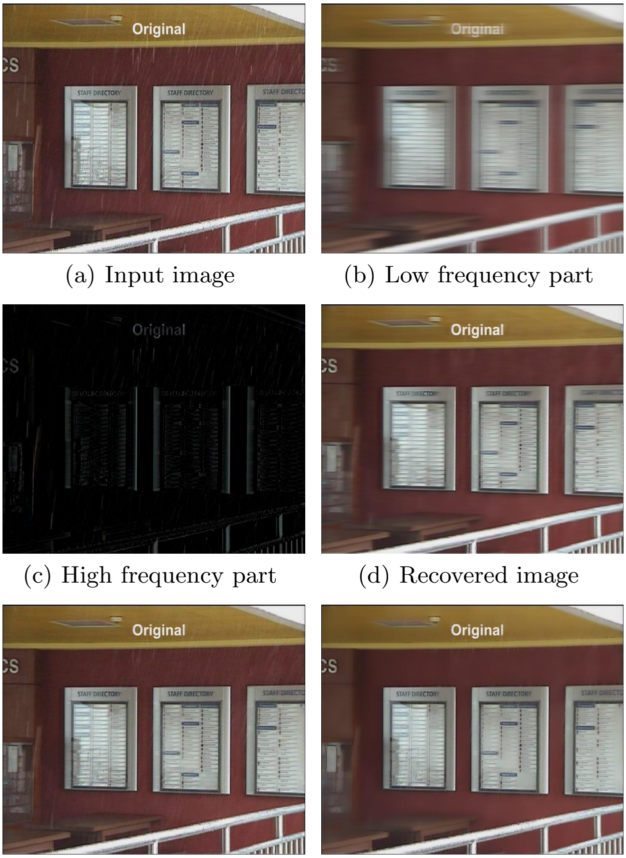
Block diagram of the proposed removal method is shown in Figure 2. It explicitly describes the framework of our method. First, input image is decomposed into low frequency part and high-frequency part by using guided filter. We introduce the low frequency part is not rain or snow part before. But due to the effect of guided filter, the edges of image become a little smooth. In order to make the existed edges more close to the edges of input image, we use edge enhancement to realize this process as follow expression:

$$I_{LF}^{*} = I_{LF} + \omega \cdot \nabla I_{LF} \tag{7}$$

where ∇I_{LF} is the gradient of I_{LF} and $\omega = 0.1$ in the paper. This enhancement is showed by the green line in Figure 1. From the Figure 1, the enhanced edges are more close to the edges of background, and all the enhanced edges are still background textures. So we get the more refined guidance image.

We don't use input image but the high-frequency part as the input image of guided filter. Since there is a big difference between the pixel values of the low frequency image and the original input image, the restored image is easy to have unsmooth flakes. The high-frequency part is more close to low frequency part, which will get better performance. After using guided filter, high-frequency part remains the non-rain or non-snow component. Through adding the low frequency part, we can get a rough recovered image.

On one hand, because we don't completely recover the edges like Fig 1(b) and just make low value pixels edges become higher, recovered image is blurred as shown in Figure 3(d). But the edges can't be rain or snow streaks, we don't



(a) Input image (b) Low frequency part

(c) High frequency part (d) Recovered image

(e) Clear recovered image (f) Refined recovered image

Fig. 3. Intermediate results in proposed method

want to change the low pixels value edges. On the other hand, using guided filter also makes recovered image blurred (such as background near to rain streaks in Figure 3(d)). So we change it to make recovered image clear as follow:

$$\mathrm{I}_{cr} = \min(I_r, I_{in}) \tag{8}$$

Due to the effect of guided filter, the values of removing rain or snow part are a little higher than nearby pixel values as shown in Figure 3(e). It is not good for our visual. So we take a weighted summation of I_r and I_{cr} to get the refined guidance image (equation 9), and then use guided filter once again to get the final result.

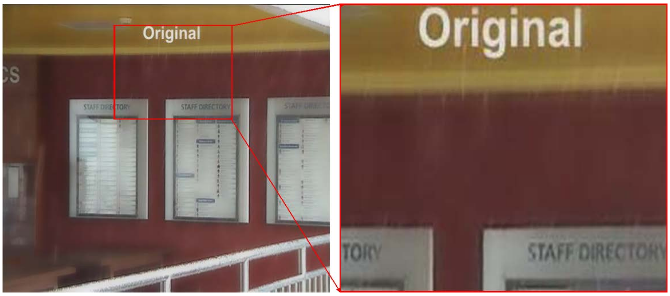
$$\mathrm{I}_{ref} = \beta I_{cr} + (1-\beta) I_r \tag{9}$$

where $\beta = 0.8$ in rain removal and $\beta = 0.5$ in snow removal in this paper.

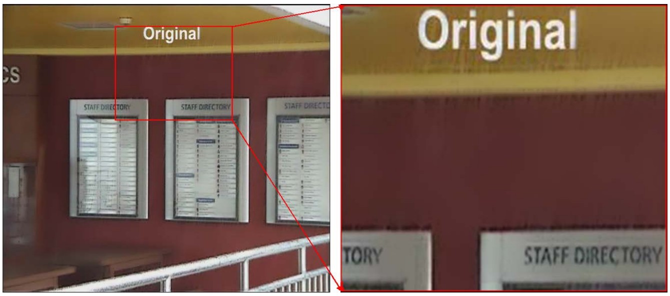
4 Experimental Results

Figure 3 shows the removal procedure and intermediate results proposed by this paper. Figure 3(b) is low frequency part of input image using guided filter in horizon(because the direction of rain streaks can't be in horizon). It indeed doesn't contain rain information. Figure 3(c) is high frequency part of input image. From the result, we can see that high frequency part has the information of background textures and rain streaks. And the rough recovered image Figure 3(d) is not rain but blurred because of guided filter. With minimize the input image and recovered image we get the clear recovered image Figure 3(e). It is clear, but has some flakes. We balance it with rough recovered image to get final result Figure 3(f), and it does not have flakes and very clear.

Figure 4 shows the best result of [11] and our result. Visually it is obvious that our result is better than the result of the method [11]. Our result is clearer and more effective in rain removal (e.g., the zoom-in region of red box). By the way, our method and method [11] both use guided filter, and guided filter is $O(N)$ time algorithm.



(a) The result in [11]



(b) Proposed method

Fig. 4. Comparison of rain removal results

Figure 5 shows a comparison between removal result of snow obtained by [11] and the result of our algorithm. Clearly, our method achieves more accurate removal of the snow. And our restored image is more clear (e.g., the background in the red box in Figure 5).

(a) Original image

(b) The result in [11]

(c) Proposed methods

Fig. 5. The removal results of snow

5 Conclusion

In this paper, we propose a new method for rain and snow removal of a single image. Through analysing the difference between clear background edges and rain or snow streaks, low frequency part can express the different characteristics of them, and then a rain and snow removal method base on low frequency is proposed. The removal part is mainly made up of guided filter. The results show that our method is effective and efficient in rain removal and snow removal. Our method and method [11] both use guided filter to remove rain and snow streaks, but our method has better performance.

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