A Review on Different Rain Removal Methods

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***Abstract*: Rain removal from a video or a single image has been an active research area over the past years. It can be done in several ways. These techniques are used in many applications such as outdoor surveillance, automatic monitoring system, outdoor recognition system, intelligent transportation system and object detection. The objective is to explore the techniques used to enhance visibility of rainy images/videos. Paper projects different techniques or methods used for the removal of rain streaks.**

***Index Terms*: Rain removal, deep learning, convolutional neural networks, image enhancement, Residual Network**

I. INTRODUCTION

Weather can impair the visual quality of images which can affect the performance of outdoor vision system. Most outdoor vision system can used for surveillance, image enhancement and object tracking. To make outdoor vision systems robust to perform in all weather conditions we need to remove the effects of weather. With the development of computer technology, outdoor vision system is being more and more widely used and it plays important role in traffic surveillance and military surveillance. However, robustness and practicability of outdoor vision system in adverse weather conditions are greatly influenced.

Weather condition such as rain, fog, haze or snow will degrade the quality of images as well as the outdoor vision system. Weather conditions vary widely in their physical properties and in the visual effects they produced in the images. Based on their differences, weather conditions can be classified as steady (fog, mist and haze) or dynamic (rain, snow and hail). In steady weather, particles are very small and steadily float in the air. In dynamic weather, rain drops are distributed anywhere in the scene and move all the time. This makes them difficult to identify and causes failures in vision applications. The dynamic weather such as rain can bring poor visibility at outdoor vision systems. The visual effects of rain are complex. Rain consist of spatially distributed drops falling at high velocities. Each drop refracts and reflects the environment which produces sharp intensity changes in an image. A group of such falling drops generate a complex time varying signal in images and videos. The images obtained by outdoor vision system in the rain have low contrast and are blurred, and it can cause serious degradation. Especially the images captured in the rain have high pollution levels and are blurred, and the ambiguous recognition of detail content makes it impossible to make application process such as feature extraction and target recognition. So it has an important significance to process the images acquired in the rain which can make the outdoor vision system have greater reliability and adaptability.

An Example of input image and output is given below:

(a) Input rainy image (b) Derained image

Fig. 1. Examples for Deraing[1].

There are variety of methods used for detecting and removing rain streaks from the images and they are classified as video based methods and single image based methods. When compared to video based methods, removing rain from a single image is significantly more difficult. It is because most of the methods are focused on separating rain streaks from object details by using low level features. When an objects structure and orientation are similar with that of rain streaks, these methods have difficulty simultaneously removing rain streaks and preserving structural information. There are various method for removing rain streaks from images and videos. Non

CNN based and CNN based methods are used to rain streaks from images and videos. Such various methods are discussed in section below.

II. PROPERTIES OF RAIN

Rain can be regarded as a collection of randomly distributed water droplets of different shapes and sizes that move at high velocities. The size of a raindrop varies from 0.1mm to 3.5 mm and its shape can be expressed as a function of its size. Smaller raindrops are generally spherical in shape. Larger drops resemble oblate spheroids. In a typical rainfall, most of the drops are less than 1mm in size, thus most rain drops are spherical[2].

The complex spatial and temporal intensity fluctuations in images produced by rain depend on several factors: (a) drop distribution and velocities; (b) environment illumination and background scene; and (c) the intrinsic parameters of the camera[2].
Based on the optical properties of a drop:

- Towards the camera raindrops refract light from a large solid angle of the environment (including the sky). Specular and internal reflections add brightness to the drop. Hence a drop tends to be much brighter than its background where the portion of the scene it occludes.
- The solid angle of the background obstructed by a drop is less than the total field of view of the drop itself. Thus, being transparent, the average brightness within a stationary drop does not depend strongly on its background.

III. LITERATURE SURVEY

This section includes analysis of various methods used for detection and removal of rain streaks from images.

A. Deep Convolutional Neural Network

It is a single image based rain removal method. Deep Convolutional Neural Networks are commonly used as deep learning network architectures. It consist of 4 layers. Convolutional Layer, Rectified Linear Unit (ReLu), Maxpooling Layer and Fully Connected Layer. In the case of rain removal based on CNN[1], Author combine the image processing knowledge with the deep learning network to improve the deraining from the images. It uses both rain removal and image enhancement technique to improve the visual effect and learns a nonlinear mapping function between clean and rainy image.

The input image is decomposed into base layer and detail layer by using a low-pass filter. Guided filter[3] is used as low-pass filter. Detail layer is the deference between the input rainy image and the base layer. Both the rain streaks and object details remains in the detail layer. CNN Architecture is Illustrated in Fig. 2:

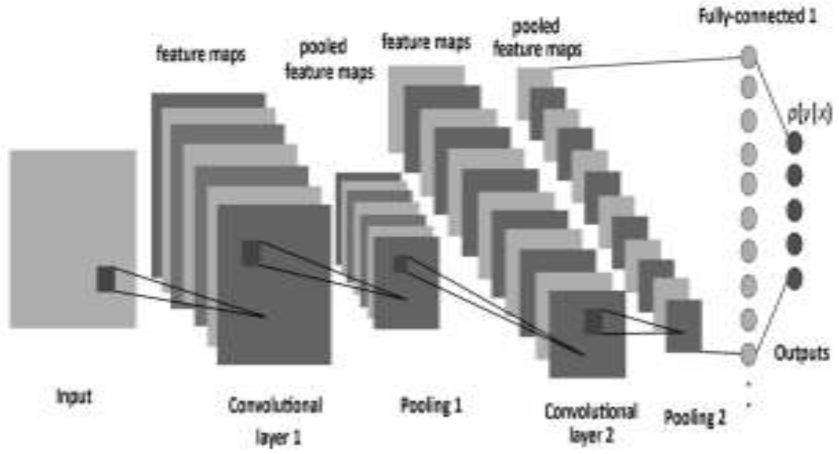


Fig. 2. CNN Architecture

This detail layer is the input of convolutional neural network (CNN). CNN has three layer which perform feature extraction and rain removal. Output of the second layer looks smoother than the output of first layer. Derained image is formed by directly adding the base layer with the output detail layer. But the image may looks hazy, thus adding enhanced base layer with the enhanced detail layer to get better visual results. Main drawback of this method is that it cannot remove the contrast variation caused by rain streaks because they do not have any processes on the base layer.

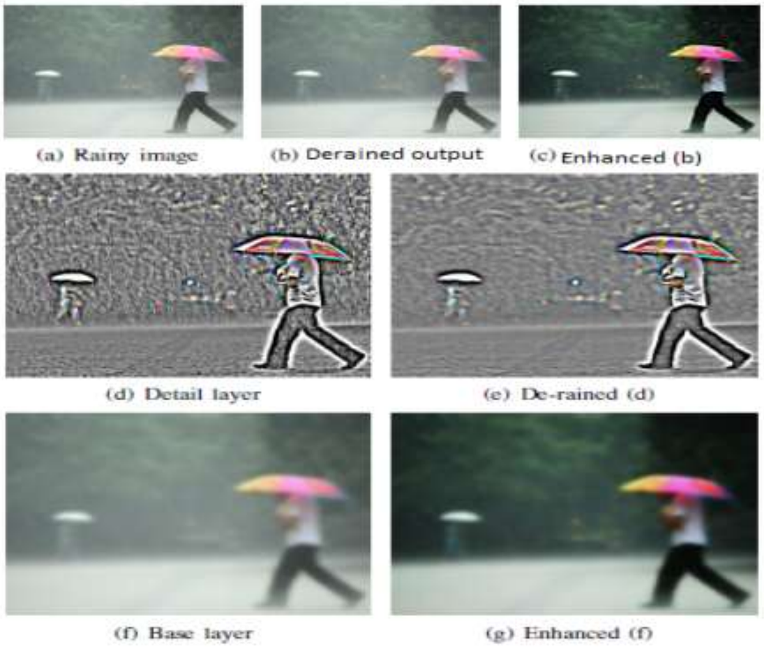


Fig. 3. Framework of rain removal using CNN

B. Residual network (ResNet)

Residual network (ResNet) [4] was introduced by Kaiming He et al which can be used to remove the rain streaks from the image. It directly reduce the mapping range from input to output can make the learning process significantly easier. The input image is decomposed into base layer by using guided filter. The base layer is subtracted from the image layer to get detail layer of the image. After subtracting the base layer, the interference of background is removed and only rain streaks and object structures remain in the detail layer. The detail layer is the input to the parameter layer. They adopt the ResNet structure [5] as the parameter layers for a deep exploration of image characteristics. Neg mapping is used along with the ResNet structure to distinguish rain streaks from the object details.

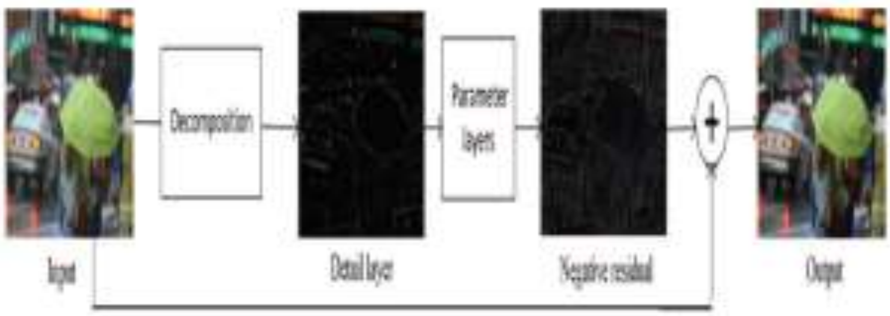
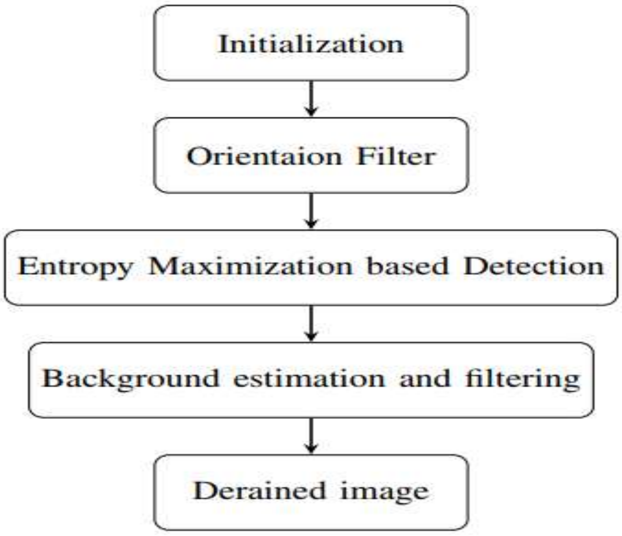


Fig. 4. Framework of rain removal using ResNet

The network structure consist of convolution operation, Batch Normalization which indicates batch normalization to alleviate internal covariate shift [6], a Rectified Linear Unit (ReLU) [7] for non-linearity and all pooling operations are removed to preserve spatial information. The de-rained image is obtained by directly adding the estimated residual to the input image.

C. Entropy Maximization and Background Estimation

Orientation filter is applied to the input image. The vertically oriented raindrops are separated from the input image. Then the Entropy maximization algorithm based residual raindrop detection is performed. The background estimation is performed using low pass filter. The orientation filter is again applied for the rain removal[8].



D. Image Decomposition

It is a single-image-based rain removal framework via properly formulating rain removal as an image decomposition problem based on morphological component analysis (MCA). For removing rain streaks from the image, the input rain image is first decompose into the low-frequency (LF) part and the high-frequency (HF) part using the bilateral filter. The most basic information will be remained in the LF part while the rain streaks and the other edge/texture information will be included in the HF part of the image. Then perform the MCAbased image decomposition to the HF part that can be further decomposed into the rain component and the geometric (nonrain) component[9].

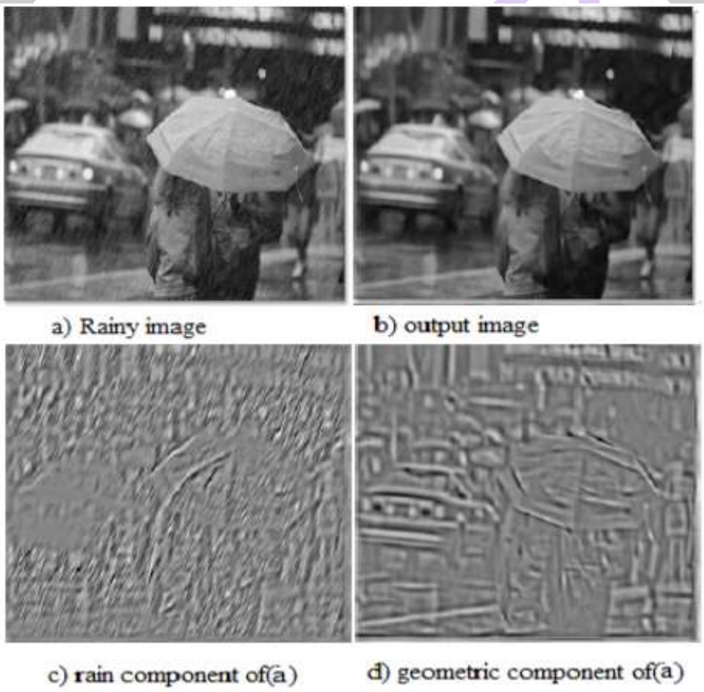


Fig. 5. Framework of rain removal using CNN

In the image decomposition step, a dictionary is learned from the training exemplars extracted from the HF part of the image itself can be divided into two sub-dictionaries by performing HOG [10] feature-based dictionary atom clustering. That is; it extracts a set of selected patches from the HF (high-frequency) part of a rain image itself to learn a dictionary. Then, based on the features extracted from individual atoms, we classify the atoms constituting the dictionary into two clusters to form two sub-dictionaries for representing the geometric and rain components of the image. Then, we perform sparse coding [11] based on the two sub-dictionaries to achieve MCA-based image decomposition, where the geometric component in the HF part can be obtained. The then geometric component is integrated with the LF part of the image to obtain the rain-removed version of the input image.

E. Saturation and Visibility Feature

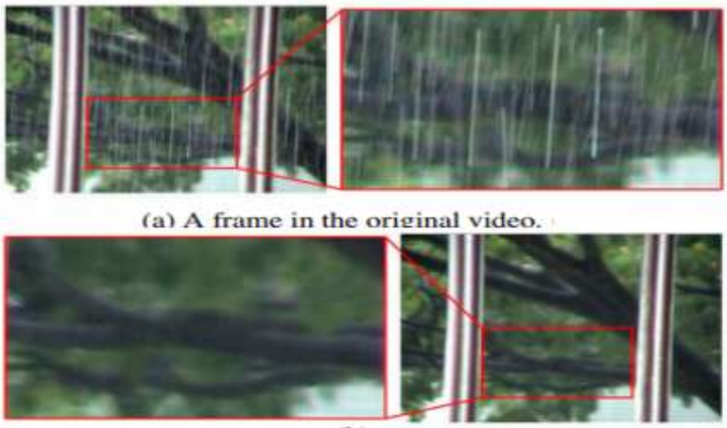
From the input image, it produces the normalized gray image which means the probability of the rain drops, to enhance the raindrops in the photographs use a high pass filter to remove the low frequency signal in the rain candidate image. Use a high pass filter in the horizontal direction to filter out the streaks which are not rain drops and we get enhanced raindrops. To get more accurate images of rain or snow we apply thresholding. We get the recovered clear image with rain removal using above thresholding[12]. The main drawback is that the resulted image still contain rain artifacts.

a) input rainy image b)Output image

Fig. 6. Example of deraining by saturation and visibility feature

F. Combining Temporal and Chromatic properties

A rain removal algorithm that incorporates both temporal and chromatic properties of rain in videos. The temporal property shows that the image pixel in the entire video is not always covered by rain. Similarly the chromatic property shows that the changes of R, G, and B values of rain-affected pixels are almost the same. Using both the properties, it can detect and remove rain streaks in stationary and dynamic scenes taken by stationary cameras.



(a) A frame in the original video.

(b) The derained result.

Fig. 7. Rain removal in static scene.

K-means clustering algorithm can be used to identify the two peaks exhibited the intensity histogram of a pixel in a video taken by a stationary camera. The intensity histogram is computed by collecting the intensity of each pixel in the image over the entire video. Then, K-means clustering is performed until converging to identify the clusters of background and rain intensities. Chromatic constraint is applied to find rain in focus and also rain that is out of focus. Defocus is a weighted average of light around a pixel, which does not affect the amounts of change ΔR, ΔG, and ΔB. Removal of detected rain pixels can be done by replacing the color of rain pixels with the corresponding background colors found by K-means clustering[13].

G. Rain Map and Temporal Filtering

It is fast rain removal method for video based method, rain streaks are removed from the videos. In the video frames, the rain streaks can be seen in a constant direction, thus we can analyze the position of rain streaks using the difference between the previous and next frames. Here rain streaks are removed based on rain map estimation. The rain map is estimated by the difference between the current and adjacent frames and is refined using the saturation channel in HSV color space and low pass filter[14]. Steps:

1.Initial rain map estimation

2.Rain map Refinement

3.Removal of rain streaks

To preserve a non-rainy region, it estimate the rain map which representing the position of the rain streaks using difference among adjacent frames. The rain streaks shows brighter intensity than other object among adjacent frames.

The rain streaks of current frame can detected by comparing the difference of intensity values between adjacent frames. The initial rain map is estimated by multiplying two difference images between current and adjacent frames. The initial rain map may contains the non-rainy objects, the initial rain map is refined using characteristic of rain streaks. The refinement of rain map is performed by using the saturation channel in HSV color space, since the rain streaks shows the low saturation value in saturation channel. Finally, the rain streaks of current frame is removed by weighted averaging of similar patch in adjacent frames.

IV. CONCLUSION

In this work, we have surveyed through various methods of rain removal from the images and videos. From the survey, we understood the methods for rain removal like Deep Convolutional Neural Network, Residual Network, Entropy Maximization and Background estimation, Image Decomposition, Rain map and Temporal filtering etc. Rain streaks removal is applicable in many applications such as image enhancement, image editing, image forensics, security surveillance and vision based navigation. Gone through several research works based on these methods, analyzed the working and their drawbacks.

REFERENCES

[1] Xinghao Ding, Yinghao Liao, Xueyang Fu, Jiabin Huang and John Paisley ”Clearing the skies: A deep network architecture for single-image rain removal”,in IEEE Transactions on Image Processing , vol. 26, no. 6, pp. 2944 - 2956, June 2017.

[2] K. Garg and S. K. Nayar,“Detection and removal of rain from videos,” in Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit. (CVPR), Jun./Jul. 2004, pp. I-528–I-535.

[3] K. He, J. Sun, and X. Tang, “Guided image filtering”, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 35, no. 6, pp. 1397– 1409, 2013..

[4] Xueyang Fu Jiabin Huang Delu Zeng2 Yue Huang Xinghao Ding John Paisley, ”Removing rain from single images via a deep detail network”, IEEE Conference on Computer Vision and Pattern Recognition, 2017.

[5] K. He, X. Zhang, S. Ren, and J. Sun.” Deep residual learning for image recognition”. In CVPR, 2016.

[6] S. Ioffe and C. Szegedy.” Batch normalization: Accelerating deep network training by reducing internal covariate shift”. In ICML, 2015

[7] A. Krizhevsky, I. Sutskever, and G. Hinton. ”ImageNet classification with deep convolutional neural networks”, In NIPS, 2012.

[8] Ruchi katre, Nitesh Dodkey,”Rain Streaks Detection and Removal in Image based on Entropy Maximization and Background Estimation”,International Journal of Computer Applications (0975 – 8887) Volume 164 – No 11, April 2017.

[9] L.-W. Kang, C.-W. Lin, and Y.-H. Fu, “Automatic single-image-based rain streaks removal via image decomposition,” IEEE Trans. Image Process, vol. 21, no. 4, pp. 17421755, Apr. 2012.

[10] N. Dalal and B. Triggs, “Histograms of oriented gradients for human detection,” in Proc. IEEE Conf. Comput. Vis. Pattern Recognit., San Diego, CA, USA, June 2005, vol. 1, pp. 886–893.

[11] S. Mallat and Z. Zhang, “Matching pursuits with time-frequency dictionaries,” IEEE Trans. Signal Process”, vol. 41, no. 12, pp. 3397–3415, Dec. 1993.

[12] K. Garg and S. K. Nayar, “When does a camera see rain?” in Proc. of IEEE Int. Conf. Comput. Vis., Oct. 2005, vol. 2, pp. 1067-1074.

[13] Xiaopeng Zhang, Hao Li, Yingyi Qi, Wee Kheng Leow, Teck Khim Ng”Rain Removal in Video by combining Temporal and Chromatic properties”.

[14] Soo-Chang Pei, Yu-Tai Tsai, and Chen-Yu Lee ,”Removing rain and snow in a single image using Saturation and Visibility Features”.

[15] Kiwoong Park, Songhyun Yu,Jechang Jeong”A Contrast Restoration Method for Effective Single Image Rain Removal Algorithm”.