

Survey of Rain Pixel Recovery For Videos With Dynamic Scenes

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ABSTRACT

Removal of rain streaks in video is a challenging problem due to the random spatial distribution and fast motion of rain. The visual effects of rain are complex. Rain consists of spatially distributed drops falling at high velocities. Each drop refracts and reflects the environment, producing sharp intensity changes in an image. This paper presents enhanced technique/s for the removal of rain effects from the dynamic videos.

Keywords

Video analysis, motion occlusion, dynamic scene

1. INTRODUCTION

Rain removal is a complex task. In rainy videos pixels exhibit small but frequent intensity fluctuations, and this fluctuation could be caused by several other reasons besides rain fall, namely, global illumination change, camera move, and object motion etc. In order to remove the rainy effect, it is necessary to detect the fluctuations that are caused by rain, and then replace them with their original value. Some good algorithms have been proposed for this purpose.

Garg and Nayar first analyzed the physical and photometric properties of the rain [1], [2], and they used their observation data to apply both intensity and temporal constraints to detect and then remove the rain. But their photometric model assumes that all rain drops have the same size and fall at almost the same velocity relative to the camera.

Weather conditions vary widely in their physical properties and in the visual effects they produce in images. Based on their differences, weather conditions can be broadly classified as steady (fog, mist and haze) or dynamic (rain, snow and hail). In the case of steady weather, individual droplets are too small (1 – 10 μm) to be visible to a camera, and the intensity produced at a pixel is due to the aggregate effect of a large number of droplets within the pixel's solid angle

This paper also focuses on the problem of rain removal in video. A new rain removal algorithm that incorporates both temporal and chromatic properties of rain in video is proposed. The temporal property states that an image pixel is not always covered by rain throughout the entire video. The chromatic property states that the changes of R, G, and B values of rain-affected pixels are approximately the same. By using both properties, the algorithm can detect and remove

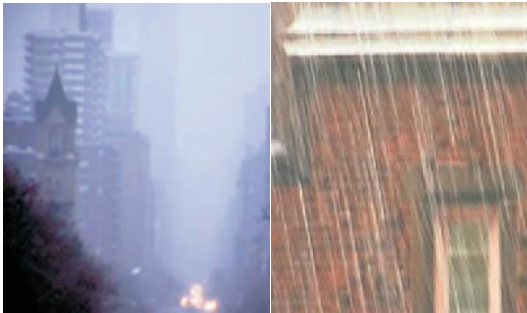
rain streaks in both stationary and dynamic scenes taken by stationary cameras. To handle videos taken by moving cameras, the video can be stabilized for rain removal, and destabilized to restore camera motion after rain removal. It can handle both light rain and heavy rain conditions. Test results show that the algorithm performs better than existing methods.



Fig 1: Rain removal in static scene. (a) A frame in the original video. (b) The derained result.

2. Steady and Dynamic Weather Conditions

Outdoor vision systems are used for various purposes such as tracking, recognition and navigation. Despite their widespread use, current systems do not account for common weather conditions such as rain, snow, fog and mist. In order to develop vision systems that perform under all weather conditions, it is essential to model the visual effects of the various weather conditions and develop algorithms to remove them. In our experiments, we used Sony DCR-TRV15E camera to take some videos with various raining scenes, including light, moderate and heavy rain in static and dynamic situations. Moreover, for comparison with the method in [3], we also tested our algorithm on the movie clips presented in [3]. Fig. 1 shows rain removal in static scene. Almost all the rain streaks are removed perfectly. The enlarged views show that both rain streaks in-focus and out-of-focus are removed completely.



(a) A scene in fog

(b) A scene in rain



(c) Rain and moving objects (d) Rain and ripples

Figure 2: The visual appearances of steady (fog) and dynamic (rain) weather conditions differ widely. (a) An image of a scene taken under foggy conditions. The intensity at each pixel is due to the aggregate effect of a large number of droplets within the pixel's solid angle. (b) An image of a scene taken on a rainy day showing streaks caused by the motion blur of individual drops. An algorithm that detects and removes rain must be robust to complex scene and camera motions as in (c) and at the same time insensitive to other time-varying textures such as water ripples as in (d).

In this work, we focus on the problem of rain. Rain consists of a distribution of a large number of drops of various sizes, falling at high velocities. Each drop behaves like a transparent sphere, refracting and reflecting light from the environment towards the camera. An ensemble of such drops falling at high velocities results in time varying intensity fluctuations in images and videos. In addition, due to the finite exposure time of the camera, intensities due to rain are motion blurred and therefore depend on the background. Thus, the visual manifestations of rain are a combined effect of the *dynamics* of rain and the *photometry* of the environment.

3. Physical Properties of Rain

Rain is a collection of randomly distributed water droplets of different shapes and sizes that move at high velocities. The physical properties of rain have been extensively studied in atmospheric sciences [4, 1]. Here, we briefly summarize these properties and make observations that are relevant to our goal of modeling the appearance of rain. The size of a raindrop typically varies from 0.1mm to 3.5 mm.

The distribution of drop sizes in rain is given by the Marshall-Palmer distribution. Figure 2(a) shows the distribution for a typical rainfall. Note that the density of

drops decreases exponentially with the drop size. The shape of a drop can be expressed as a function of its size [1]. Figure 2(b) shows the shapes of raindrops of various sizes. Smaller raindrops are generally spherical in shape while larger drops resemble oblate spheroids. In a typical rainfall, most of the drops are less than 1mm in size, as seen in Figure 2(a). Hence, most raindrops are spherical and we will use this approximation in our work. As a drop falls through the atmosphere, it reaches a constant

terminal velocity. The terminal velocity v of a drop is also related to its size a and is given by [4]

$$v = 200\sqrt{a}, \quad (1)$$

where a is in meters and v is in meters/s.

4. Appearance Model for Rain

In this section, we analyze image formation through rain. 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. We first develop a correlation model that captures the dynamics of rain based on the distribution and velocities of raindrops.

Then, we develop a physics-based motion blur model that describes the brightness produced by streaks of rain.

5. Detection of Rain in Videos

Based on the dynamics and photometric models of rain, we now develop a robust algorithm to detect (segment) regions of rain in videos. Although our models do not explicitly take into account scene motions, we will show that they provide strong constraints which are sufficient to disambiguate rain from other forms of scene motions.

6. Removal of Rain from Videos

Once the video is segmented into rain and non-rain regions, we apply the following simple method to remove rain from each frame of the video. For each pixel with rain in the n th frame, we replace its intensity I_n with an estimate of the background obtained as $(I_{n-1} + I_{n+1})/2$ (see Figure 5(b)). This step removes most of the rain in the frame. However, since drop velocities are high compared to the exposure time of the camera, the same pixel may see different drops in consecutive frames. Such cases are not accounted for by our detection algorithm. Fortunately, the probability of raindrops affecting a pixel in more than three consecutive frames is negligible. In the case of a pixel being affected by raindrops in 2 or 3 consecutive frames, we remove rain by assigning the average of intensities in the two neighboring pixel (on either side) that are not affected by raindrops. Our results show that this additional step can be very effective for rain removal. Note that we only remove streaks that can be detected. Severely defocused streaks and streaks on bright backgrounds produce very small changes in intensities that are difficult to detect in the presence of noise. Hence, we are unable to remove such streaks. In addition, we do not handle the steady effects of rain in this work. Raindrops far from the camera are much smaller than a pixel. Hence, the intensity at a pixel is due to a large number of drops in the pixel's field of view. These aggregate effects are similar to the effects of fog. Hence, defogging algorithms [10] can be used to remove the steady effects of rain.

Conclusion

In this paper we have studied the previous works on removal of rain effects from dynamic videos. From each paper we have studied the problem, their methodology used to overcome the problem, their analysis and finally future plan. Our survey shows that the existing algorithms and techniques perform poorly in dynamic scenes. The researcher has scope to improve the performance of dynamic scenes of rainy videos.

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