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Taxonomy of rain detection and rain removal techniques

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Abstract

There are number of occurring weather conditions phenomena. Bad weather condition such as rain can lead to image degradation of the captured image or video. The visual effects produced by rains are very complex due to the properties of raindrops that can reflect and refract the environment. A common solution to reduce the visibility of rain is by using filtering techniques. This paper intends to give a summary on the raindrop detection and removal techniques that has been used in order to enhance the weather degraded images. The merits and demerits of the rain detection and removal are discussed to motivate the further research. The analysed and studied techniques on rain detection and removal techniques will become the fundamental to design the fundamental of this study to produce an efficient technique in rain detection and removal and applicable for real-time application. We believe this study on detection and removal of rain can be used in many applications such as image or video editing, surveillances vision system and Vision-based Driver Assistance Systems (DAS).

Introduction

Digital image processing is one of the popular research topics among the researcher. The techniques of digital image processing began almost 60 years ago and used in medical imaging, remote Earth resources observation and astronomy. Digital image processing focuses on two major tasks which are the improvement of pictorial information for human interpretation and processing of image data for storage, transmission and representation for autonomous machine perception (Gonzalez, 2008). In recent years, digital image processing has expanded and used in many task such as image enhancement and restoration, artistic effects, medical visualisation, industrial inspection, law enforcement and human computer interfaces.

This paper focuses on the successful techniques that have been implemented by researchers in order to detect and remove raindrops from images or videos. An overview of bad weather definition identified from images or videos are also discussed in this paper.

Literature Review

This section is divided into three which are the bad weather classification, rain detection and rain removal. In the bad weather classification, further explanation is presented whereas the rain detection and removal discusses on the techniques that has been used to remove rain from images.

Bad Weather Classification

Weather is defined as the current atmospheric condition such as the temperature, rainfall, wind and humidity (Henderson *et al.*, 1993). Bad weather condition can be classified into two which are the static or steady weather condition and dynamic weather condition. The static weather condition including fog, mist and haze whereas the dynamic weather condition are rain, hail and snow (Halimeh & Roser, 2009). Figure 1 shows the classification of bad weather condition.

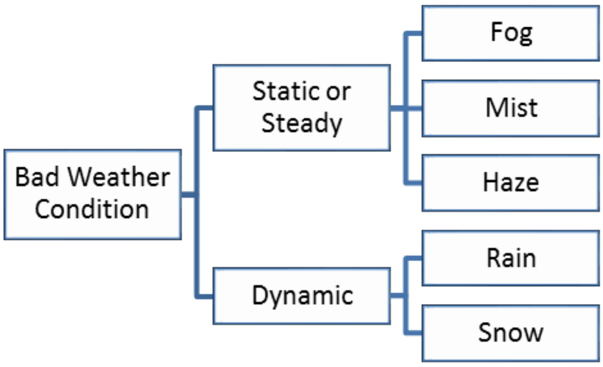

Figure 1: Bad weather classification (Abd Wahab *et al.*, 2013)

Static or steady weather particles are too small to be visible on the camera (Garg & Nayar, 2004). Radius of the particles are 1-10 µm and float steadily in the air. The particles of the dynamic weather condition are larger (0.1-10 mm) enough to affect visibility and visible on the images.

This paper focuses on the dynamic weather condition which is rain. Rains consist of randomly distributed water droplets with various shapes and size falling with high velocities. The properties of rain produced sharp fluctuation intensity lead to degradation of images and videos. Due to the properties of rain that can cause spatial and temporal effects on the image, Narasimhan & Nayar (2002) state that rain should be treated differently from the static weather condition.

Rain Detection

Detection algorithm is a task to identified the location of damage sample as precisely as possible. In this study we will consider the damaged pixels cause by rain. Based on the temporal properties of rain, the rain will not affects one pixel only but it will also damage the neighbouring pixels. Removal is used to remove the detected rain pixels from the image in order to get an image without rain.

The research of rain detection encourage by Narasimhan & Nayar in 2003 as they develop a model to detect bad weather condition in images. Barnum & Narasimhan (2010) in their paper state that the detection algorithm can be classified into four; no explicit detection, per-pixel detection, patch-based detection and frequency-based detection. Figure 2 summarize the detection algorithm that has been used by researchers.

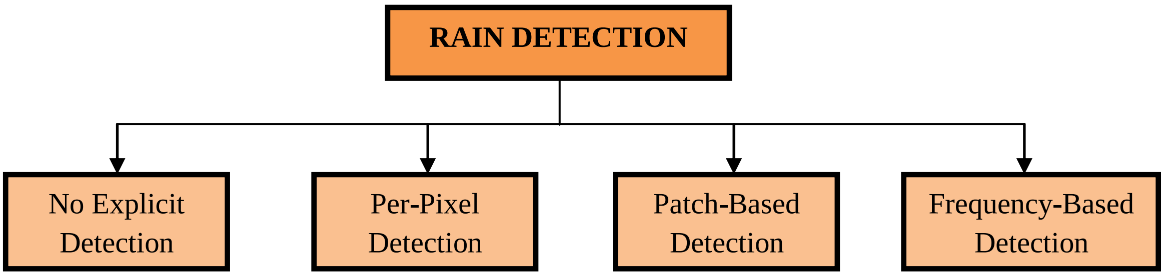

Figure 2: Taxonomy of rain detection in image (Barnum *et al.*, 2010)

a) No Explicit Detection

Some researchers did not perform the detection algorithm to remove rain from images. Narasimhan & Nayar (2003) deal with single image of mild rain. Since the faraway image of rain is taken, the image looks like in a foggy condition. Figure 3 shows the image taken during misty and rainy weather condition.

(a) (b)

Figure 3: (a) Misty image (b) Rainy image (Narasimhan & Nayar, 2003)

Since both images almost the same, Narasimhan & Nayar (2003) used the same algorithm to restore the contrast of the rainy image. Some researchers simply applied filtering to remove the rain from the images (Starik & Werman, 2003; Shariah *et al.*, 2011). Coincidentally, this technique will performs poorly when it is applied to the moving objects scene.

b) Per-Pixel Detection

As stated in the previous section, the pixels of an image can be divided into rain and non-rain part. Zhang *et al.* (2006) implement k-means to the grayscale intensity of each pixel to divide the pixels into the rain part and non-rain part. Since the rains have temporal properties, some pixels are misclassified.

c) Patch-Based Detection

This detection detects the region of rain in an image. By applying the constraints of photometric model in each frame in the video, Garg & Nayar (2004) manage to detect the candidate rain pixels. For a three frames static background scene, the intensities of previous frame (I_{n-1}) must be equal to the intensities of the next frame (I_{n+1}) and the change of intensities in the current frame (n^{th}) must satisfy the constraint, c (threshold: minimum change in intensity produced by a raindrop that detected in the presence of noise).

When this constraint of photometric model applied to a scene with an object motions, this algorithm will detect some false positives due to the movement of the object (Garg & Nayar, 2004). Barnum *et al.* (2010) found that this algorithm fail to detect individual streaks in an image (Barnum *et al.*, 2010). Figure 4 shows the detection of rain by Garg & Nayar (2004).

(a) (b)

Figure 4: (a) original image with rain. (b) Rain segmented region after applying the constraint of photometric model (Garg & Nayar, 2004)

d) Frequency-Based Detection

Barnum et al. (2010) used spatio-temporal frequency method to detect rain in an image. The inverse transform of the estimated proportion of energy of rain is used to detect the rain streak in a single frame.

Rain Removal

Rain removal techniques can be applied to rain degraded images. According to Tripathi & Mukhopadhyay (2014), rain removal techniques can be divided into two main approach which are time domain-based approach and frequency domain-based approach. In the time domain-based approach basically considered the properties of rain itself including the chromatic, temporal or both. Figure 5 shows the taxonomy of rain removal.

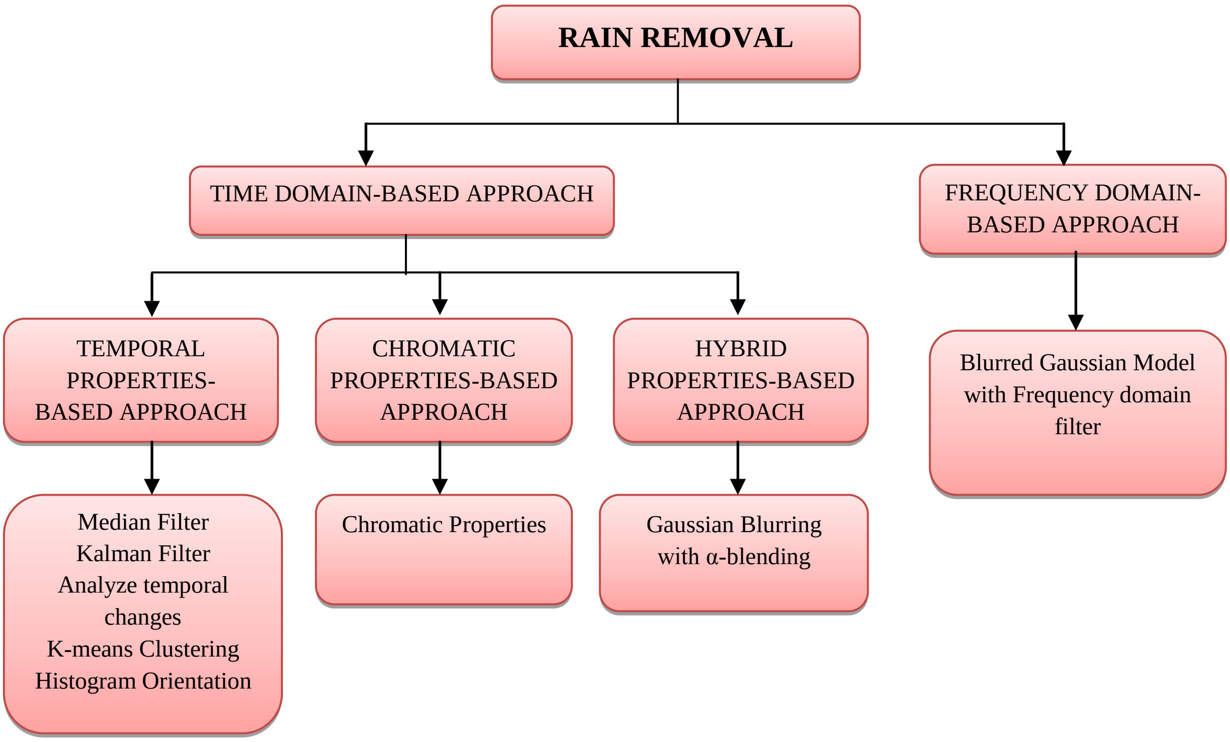

Figure 5: Taxonomy of rain removal techniques (Tripathi & Mukhopadhyay, 2014)

a) Temporal Properties-Based Approach

Due to the temporal properties, rains are not remain fixed at one time. For a static scene, Starik & Werman (2003) applied temporal median filter for each pixel to reduced rain effects from images. Even though this technique is one of the easiest technique to remove rain from images, but this technique will produce blurring when applied on a dynamic scene. By taken the advantage of temporal properties of rain, Park & Lee (2008) proposed new algorithm which is the intensity estimation by using Kalman filter in a real time situation. Since this algorithm estimated that the video captured by using a static camera with static background, therefore it is fail to estimate the pixels' intensity in a dynamic background.

b) Chromatic Properties-Based Approach

The chromatic properties-based approach proposed by Liu *et al.* (2008) deal with colored pixel images. By using the chromatic properties, two relations between the same pixels in two consecutive frames can be developed (Liu *et al*., 2008). As the raindrop falling to the ground, it will affect the pixels' intensity. Therefore, the first relation is between the background pixel and the rain-affected pixel where the rain-affected pixels are brighter than the background and there are two related rain-affected pixels in the consecutive frames.

To restore the rain-affected pixels, the intensity of neighbourhood is used to estimate the background value. The disadvantage of this technique as stated by Tripathi &

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Mukhopadhyay (2013), this technique fails to differentiate between the rain pixels and the moving object pixels.

c) Hybrid Properties-Based Approach

Basically, a hybrid properties-based approach is the composite of both temporal and chromatic based approach. Due to the temporal properties of rain, the raindrops are not fixed at a particular pixel in all frames and the chromatic properties of raindrops stated by Zhang *et al*. (2006) show that the intensity changes of R, G and B channels due to the raindrops are approximately the same. The raindrop pixels are detected by applying the K-means clustering to the intensity histogram of the video. In the process of removing the raindrops, Zhang et al. (2006) applied dilation with Gaussian blurring to the detected pixels and then used them as the α channel. The raindrops are removed from the videos by using α-blending technique.

d) Frequency Domain-Based Approach

This approach basically analyse the frequency information of each frame. Proposed by Barnum et al. in 2010 can be applied in either single frame or multiple consecutive frames. After the rain streaks detected by using rain detection in section 2.2 (d), the removing of rain pixels can be done by replacing them with their temporal neighbours.

This method rarely removes the rain streak completely but it will modify the brightness of rain streak by reducing the brightness. Figure 6 show the rain removal based on spatio-temporal frequency detection.

Figure 6: Image taken in front of windowed building with mild rain condition. Some false detection occurred near the window frames and bushes (Barnum et al., 2010)

Challenges

In a dynamic weather condition such as rain, there are several issues need to be dealt with. As mentioned above, the temporal and spatial properties of rain can cause degradation in images and videos. According to Abd Wahab *et al*. (2013), the main challenges in rain detection and removal is to invent a technique with low computational cost and can be operated in real time situation.

The raindrops can refract and reflect the scene radiance and atmospheric illumination produced a complex visual of raindrops. Garg & Nayar (2004) states that due to the refraction and reflection, the raindrops are brighter than its background. As declared in the above section, raindrops are randomly distributed and moving at high velocity. The movement of raindrops with very high velocity known as rain streaks and will produced spatial and temporal intensity variation in image and video. Video handled in rain removal techniques can be divided into two, which are the static video and dynamic video. According to Tripathi & Mukhopadhyay (2014), a video is a dynamic video when it contains moving objects and it is a static video when the background is static images. When dealing with dynamic videos, more frames is needed to detect and remove the rain streak. Therefore, the removal of rain will consume high computational cost.

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Application of Rain Detection and Rain Removal

The techniques of detection and removal of rain can be applied in many applications such as in image and video editing. There are some situations where the image taken by photographer contains noise such as rain in the image. Sometimes they have to remove the noise to get a beautiful picture. Therefore by using the detection and removal techniques, the image taken can easily restored. On the other hand, the rain detection and removal techniques are very important in the filming industries and video editing. Although the video is taken during rainy day, they can easily remove the unnecessary noise such as rain from their videos. Object detection and recognition is very important in surveillance vision system. But the performance of this system will degraded when the weather is in bad condition. By using the techniques of rain detection and rain removal, the system will automatically removes rain streak from the captured video. Some driver assistance systems (DAS) use video images in order to give information related to traffic (Tripathi & Mukhopadhyay, 2013). During the rain, the performance of this system will become contemptible. By implementing rain detection and rain removal into the systems, the captured video of DAS will improved without the presence of rain.

Conclusion

In this paper, the rain detection and rain removal techniques used by researchers has been discussed. Each and every technique has its own advantages and disadvantages. Some researchers simply improve and enhance the applicable technique and there some that invent a new technique. The detection and removal of rain is very challenging because rain has spatial and temporal properties that can effects the neighbouring pixels in an image. Since the raindrop has spatial and temporal properties, it will affect the neighbouring pixel as well. These properties harden the process of detection of raindrops because it will detect the moving object as well. Therefore, our research direction will enhance the issues on the detection of rain in a single image.

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