INTEGRATION OF ENHANCED DICTIONARY LEARNING AND MAGNITUDE COMPUTATION TECHNIQUES FOR REMOVING RAIN STREAKS IN DIGITAL IMAGE ENHANCEMENT

RAIMA BINTI HASSIM

FACULTY OF SCIENCE AND NATURAL RESOURCES
UNIVERSITY MALAYSIA SABAH
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RAIMA BINTI HASSIM

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, quotations, summaries, and references, which have been dully acknowledged.

27 AUGUST 2017

RAIMA BINTI HASSIM

MS1421112T

CERTIFICATION

NAME : **RAIMA BINTI HASSIM**

MATRIC NO. : **MS1421112T**

TITLE : **INTEGRATION OF ENHANCED DICTIONARY LEARNING AND MAGNITUDE COMPUTATION TECHNIQUES FOR REMOVING RAIN STREAKS IN DIGITAL IMAGE ENHANCEMENT**

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CERTIFIED BY

1. SUPERVISOR Signature

Assoc. Prof. Dr. Abdullah Bade ________________

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ABSTRACT

Rain streaks detection and removal are very important topics in the field of image processing and computer vision. The present of rain in images and videos causing the pixels in the image corrupted. The main problem in this research is to detect and remove rain streaks. The aim of this research is to develop an efficient technique that able to detect and remove rain streaks from a single image. The proposed technique consists of two main parts which are the rain streaks detection and rain streaks removal. Both rain streaks detection and rain streaks removal are combined and known as HyDRa. At first, the contrast of the image will be enhanced followed by bilateral filtering technique to divide the input image into two parts, low frequency, and high-frequency part. The classification of rain component and non-rain component is done when the high-frequency part of the image undergoes the dictionary learning approach. For achieving smooth detection of the rain streaks process, the magnitude of each pixel in the rain component will be computed. As for the removal stages, the non-rain component is subtracted from the image and will be combined with the low-frequency part from the filtering stage. The PSNR test and SSiM test of HyDRa for image 1 are 31.09 dB and 0.9194 respectively. Based on the performance test, the PSNR values for test images are significantly better as compared to the classical technique such bilateral filtering approach and self-learning dictionary approach.

ABSTRAK

INTEGRASI TEKNIK PEMBELAJARAN PUSTAKA YANG DITAMBAHBAIK DENGAN PENGIRAAN MAGNITUD UNTUK MENYINGKIRKAN JALUR HUJAN PADA ENHANCEMENT IMEJ DIGITAL

Pengesanan dan penyingkiran jalur-jalur hujan pengesanan adalah topik yang sangat penting dalam bidang pemprosesan imej dan visi pengkomputeran. Kehadiran hujan pada imej dan video menyebabkan piksel-piksel imej rosak. Masalah utama dalam kajian ini adalah untuk mengesan dan menyingkirkan jalur-jalur hujan. Tujuan kajian ini adalah untuk membangunkan satu teknik yang cekap yang dapat mengesan dan membuang jalur-jalur hujan daripada imej tunggal. Teknik yang dicadangkan terdiri daripada dua bahagian utama iaitu pengesanan jalur-jalur hujan dan penyingkiran jalur-jalur hujan. Kedua-dua teknik pengesanan jalur-jalur hujan dan penyingkiran jalur-jalur hujan digabungkan dan dikenali sebagai HyDRa. Pada mulanya, kontras imej akan dipertingkatkan sejajar dengan menggunakan teknik penapisan dua hala menghasilkan dua bahagian imej iaitu imej frekuensi rendah dan imej frekuensi tinggi. Kemudian imej frekuensi rendah melalui proses pembelajaran pustaka dan imej frekuensi tinggi diklasifikasikan kepada komponen hujan dan komponen bukan hujan. Untuk mencapai pengesanan kelancaran proses jalur-jalur hujan, magnitud setiap piksel dalam komponen hujan akan dikira. Bagi peringkat penyingkiran, komponen bukan hujan ditolak dari imej dan akan digabungkan dengan bahagian frekuensi rendah dari peringkat penapisan. Ujian PSNR dan ujian SSiM Hydra untuk imej 1 masing-masing adalah 31.09 dB dan 0,9194. Berdasarkan ujian prestasi, nilai PSNR untuk imej ujian adalah jauh lebih baik berbanding teknik klasik seperti pendekatan penapisan dua hala dan pembelajaran pustaka kendiri.

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CHAPTER 1

INTRODUCTION

1.1 Preface

There are many kinds of bad weather condition in our daily life namely fog, mist, haze, rain and snow. Bad weather conditions can be classified into steady weather conditions (fog, mist, and haze) and dynamic weather conditions (rain and snow). The individual droplets of steady weather conditions are too small (1-10 µm) to be visible on the camera. On the other hand, the individual droplets of dynamic weather conditions are larger (0.1-10 mm) and will be visible in the image (Garg and Nayar, 2004). When an image or video is captured during the rainy situation, the moving raindrops will cause the rain streaks effect on the image or video which will reduce the efficiency of computer vision approaches.

Currently, many researchers concentrate on the restoration of either image or video. The image taken during bad weather condition is mostly degraded due to the presence of image noises which can also affect the existing computer vision algorithms. The dynamic weather condition such as rain will be considered in this thesis. Since rain streaks will appear in the rain degraded image, the rain streaks detection is helpful for the rain streaks removal process in order to restore the image visibility and produce a rain-free image.

1.2 Problem Background

Bad weather conditions cause the degradation of an outdoor image. Bad weather conditions can be divided into two conditions which are static (fog mist and haze) and dynamic (rain and snow). On the other hand, bad weather conditions affect the captured image or video due to the presence of aerosol substances and the properties of weather act as a medium for reflection, refraction, and absorption of light (Garg and Nayar, 2004).

Different types of weather will cause different noise effect on the image. Although researchers proposed many techniques to remove noise from the image, there is no exact technique that succeeded in removing noise in all bad weather condition (Tripathi and Mukhopadhyay, 2012). Since there is no standard type of image used in computer vision and image processing, most of the computer vision and image processing techniques are not beneficial (Shotton *et. al*, 2013).

The presence of numerous weather conditions drives the researchers to develop many techniques in order to restore the weather degraded image. These image restorations are including noise removal, haze removal, fog removal, cloud removal, snow removal and rain removal. The restoration and enhancement of image taken during various weather condition become the considerable topic among the researchers (Sánchez *et. al*, 2013).

Image segmentation technique is a process where the image is divided into several regions according to the similar features in the image. There are many techniques considered as good techniques including two major approaches which are region-based techniques and boundary-based techniques (Dougherty, 2009). Automatic video segmentation proposed by Wang *et. al* (2007) can be divided into three types of segmentation including watershed-based segmentation, image segmentation, and change-detection based segmentation. Although these techniques are able to remove rain streaks, it is only applicable to video applications.

In the area of image processing, the topic of noise removal and image restoration has become the most growing research topic among the researchers. This topic mainly focused on the images or videos that are captured during bad weather condition. Most of the previous researchers focused on the video or image sequence restoration that requires many frames in order to remove noise from the image and restore its visibility (Barnum *et. al*, 2010; Liu *et. al*, 2008; Park and Lee, 2008a; Tripathi and Mukhopadhyay, 2012; Xiaopeng *et. al*, 2006). Although most of the proposed techniques are able to restore the image or videos, the computational costs are higher as more frames are required.

As for the fog and haze removal, the typical techniques used to restore the degraded image are filtering and histogram equalization. Both techniques have low computational cost but the output image is unconvincing due to the information loss of the background image. When dealing with foggy or hazy image, the depth of fog or haze must be taken into consideration. Nevertheless, both techniques are not suitable for dense fog or haze regions. One of the best techniques to remove haze is by using depth technique and wavelet technique. However, these techniques require more frames to produce better results (Saggu and Singh, 2015; Wang *et. al*, 2015).

Simple image processing technique is not valid for the dynamic weather such as rain due to the properties of rain. The properties of rain which are the reflection and refraction of light are difficult to detach its background (Garg and Nayar, 2007). Thus, it is advised by many researchers that it is better to remove rain streaks from the video and images so as to detach the properties of rain from an image.

Rain streaks in the video are easily removed when more frames are available. It was suggested by Barnum *et al.*, (2010) that by combining statistical properties of streaks and its effect in frequency space, it will ease the process of detection and removal of rain streaks in the video. The chromatic property of rain aids the process of detecting the rain affected pixels from the background (Liu *et al.*, 2008; Park and Lee, 2008a). For removal of rain streaks in the video, Liu *et al.*, (2008) recovered the de-rained version of the video by using the inpainting technique. Another technique of rain streaks removal is the intensity estimation by using Kalman filter proposed by Park and Lee (2008a). This technique recursively calculates the intensity for real-time processing but only applicable for the stationary camera.

Although the techniques of rain streaks removal in the video give good results in removing the rain streaks, the computational cost is higher as most of the techniques need two or more consecutive frames (Wahab *et. al*, 2013). To reduce the computational cost, several researchers proposed the removal of rain streaks in a single image (Barnum *et. al*, 2007; Fu *et. al*, 2011a; Huang, Kang *et. al*, 2014; Huang, Kang *et. al*, 2012a; Kang *et. al*, 2012; Kim *et. al*, 2013; Luo *et. al*, 2015; Pei *et. al*, 2014; Xu *et. al*, 2012a; Xu *et. al*, 2012b; Yeh *et. al*, 2015; Yu *et. al*, 2015; Zheng *et. al*, 2013).

The present of rain streaks in the image or videos has three main properties including temporal property, chromatic property, and intensity property. The temporal property states that the rain streaks will not remain constant, not at one pixel at one time and it might corrupt the neighboring pixels as well (Xiaopeng *et al.*, 2006). Since the rain streaks have temporal properties, the process of rain streaks removal takes a long time. It might produce blurring in the image and at the same time, it removes the background edges (Kim *et al.*, 2013). Presently, the researchers are demanding a technique that has low computational cost or time and applicable to the real-time application (Wahab *et al.*, 2013).

The research on rain streaks primarily divided into two categories which are rain streaks detection and rain streaks removal. Both categories focus on detecting or removing rain streaks either from images or videos. Rain streaks detection generally can be divided into four main techniques including No Explicit Detection, Per-Pixel Detection, Patch-Based Detection and Frequency-Based Detection. For No Explicit detection technique, the researcher applied image enhancement and image filtering without detecting the rain streaks. Per-pixel detection will detect the rain streaks pixel by pixel whereas Patch-based detection will detect the region that contains rain streaks. Frequency-based detection detects the rain streaks based on the frequency space. Further explanation on the rain streaks detection will be described in Chapter 2.

There are several video rain streaks removal approaches had been proposed namely Temporal properties-based approach, Chromatic properties-based approach, Hybrid properties-based approach, and Frequency domain-based approach. For temporal properties-based approach, Starik and Werman (2003) proposed to reduce the rain streaks by applied the temporal median filter to every pixel. On the other hand, Park and Lee (2008b) proposed to use the Kalman filter in real time video rain streaks removal. Frequency domain-based approach can remove the rain streaks by analyzing the frequency information of every frame.

For chromatic properties-based approach, Liu *et al*. (2008) proposed to estimate the background value based on the intensity of neighborhood as the rain affected pixels are brighter than the background. However, this approach unable to separate the rain streaks and the moving object (Tripathi and Mukhopadhyay, 2013). Hybrid properties-based approach is based on the temporal properties and chromatic properties-based approach. For this approach, Zhang *et al*. (2006) proposed a video rain streaks removal technique where the rain streaks are detected by using Gaussian blurring and removed by using the α-blending technique.

Many video rain removal techniques are not applicable to single rain degraded image as these techniques required two or more frames (Jha *et. al*, 2013; Kalia and Jaikar, 2011; Kim *et. al*, 2015, Xu *et al*., 2012b). The main technique that is applied to remove the rain streaks from a single rain degraded image is dictionary-based techniques. The dictionary-based technique is able to remove the rain streaks from the single image but it requires more time due to the complexity of the technique (Fu *et. al*, 2011b; Huang *et. al*, 2012b; Kang, *et al*., 2012; Yeh *et al*., 2015). The other technique for single image rain streaks removal is the filtering-based approach. For example, Xu *et al.* (2012a) proposed to remove the rain streaks by using guided image filter.

1.3 Problem Statement

When a video or image captured during a rainy day, they will be covered with streaks from the moving raindrops. This effect will degrade the effectiveness and quality of output of any computer vision algorithm. An individual raindrop only affects a small number of the pixel but a collection of them will affect the neighboring pixels. This is