ENHANCED DETAIL & DEHAZE TECHNIQUE (DDE) FOR STATIC HAZE IMAGE IMPROVEMENT

DANNY NGO LUNG YAO

FACULTY SCIENCES AND NATURAL RESOURCES
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ENHANCED DETAIL & DEHAZE TECHNIQUE (DDE) FOR STATIC HAZE IMAGE IMPROVEMENT

DANNY NGO LUNG YAO

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2018

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DECLARATION

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28 FEBRUARY 2017

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CERTIFICATION

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DEGREE	:	**MASTER OF SCIENCE (COMPUTER GRAPHICS WITH MATHEMATICS)**
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ABSTRACT

This research is related to the removal of the haze effects from a haze degraded image and enhances the image details. The Enhanced Detail & Dehaze technique (DDE) is proposed in order to satisfy the aim of developing an enhanced method by integrating modified channel prior scheme and enhanced Son method. The development of modified channel prior is inspired by the dark channel prior and bright channel prior where the modified channel prior is proposed as a prior that there are many dark pixels and bright pixels exist in the haze-free outdoor image. The haze removal using modified channel prior scheme is able to remove the haze effects from the haze degraded image. On the other hand, the enhanced Son method proposed by enhancing the Son method in order to overcome the limitations of the Son method, such as the brightness reversal, increasing noise and the problem of sky regions segmented into heterogeneous regions. The enhanced Son method is able to enhance the image detail and provides a level of detail control. Both modified channel prior scheme and enhanced Son method are integrated to form the proposed DDE method. The DDE method computes the modified channels based on the modified channel prior and estimates the global atmospheric light by selecting the brightest pixel among the modified channels. The transmission will be estimated with the global atmospheric light and modified channels. After that, a dehazed image will be obtained by solving the atmospheric scattering model. An image can be decomposed into base layer and detail layer. The DDE method smoothes the input image with guided image filter where the box filter contained inside had replaced by Gaussian smoothing. Later, the detail layer is obtained by subtracting the smooth image from the input image. A non-sky detail layer is proposed as the combination of the detail layer and the transmission. After that, the non-sky detail layer will be recombined with the dehazed image based on the tone transform model. The recovered image is then post processed based on the histogram equalization for the contrast enhancement. Based on the MSE and PSNR test, the DDE method obtained a better result in average as the MSE value is lower and the PSNR is higher compared to the Gibson method and the dark channel prior scheme. For instance, the sample image 1 shows the 17.1142 dB for the dark channel prior scheme, 15.0476 dB for Gibson method and 17.4007 dB for the DDE method in the PSNR test. Based on the MSSIM test, the DDE method indicated the structure of the recovered image is different with the original one compared with the other previous works. Overall, the proposed DDE method is able to remove the haze effects and enhance the image details. The DDE method also overcome the limitations of the Son method, dark look, and block or halos effects.

ABSTRAK

KAEDAH ENHANCED DETAIL & DEHAZE (DDE) UNTUK PENINGKATAN IMEJ JEREBU STATIK

Kajian ini adalah berkaitan dengan pembuangan kesan jerebu daripada imej jerebu dan meningkatkan butiran imej. Kaedah Enhanced Detail & Dehaze (DDE) adalah dicadangkan untuk memenuhi matlamat untuk membangunkan kaedah yang dipertingkatkan dengen mengintegrasikan pra saluran yang diubah suai dan kaedah Son yang diubah suai. Pembangunan pra saluran yang diubah suai adalah diilhamkan oleh pra saluran gelap dan pra saluran terang di mana pra saluran yang diubah suai telah dicadangkan sebagai prior bahawa terdapat banyak piksel gelap dan piksel terang wujud dalam imej yang bebas daripada kesan jerebu. Pembuangan kesan jerebu menggunakan skim pra saluran yang diubah suai mampu menghilangkan kesan jerebu daripada imej jerebu. Sebaliknya, kaedah Son yang diubah suai dicadangkan dengen meningkatkan kaedah Son untuk mengatasi batasan kaedah Son, seperti pembalikan kecerahan, kebisingan yang semakin meningkat dan masalah kawasan langit dibahagikan kepada kawasan-kawasan yang heterogen. Kaedah Son yang diubah suai mampu meningkatkan butiran imej dan menyediakan kawalan tahap perincian. Kedua-dua skim pra saluran yang diubah suai dan kaedah Son yang diubah suai disepadukan untuk membentuk kaedah DDE yang dicadangkan. Kaedah DDE mengira saluran yang diubah suai berdasarkan pra saluran yang diubah suai dan menganggarkan cahaya atmosfera global dengan memilih piksel yang paling terang di antara saluran yang diubah suai. Transmisi akan dianggarkan dengan cahaya atmosfera global dan modiifed channels. Selepas itu, imej dehazed diperoleh dengan menyelesaikan model serakan atmosfera. Imej boleh dipecahkan kepada lapisan asas dan lapisan lanjut. Kaedah DDE melicinkan imej input dengan penapis imej berpandu di mana penapis kotak yang terkandung dalam telah digantikan dengan pelicin Gaussian. Kemudian, lapisan lanjut diperolehi dengan menolak imej lancar dari imej input. Satu lapisan detail bukan langit dicadangkan sebagai gabungan lapisan lanjut dan transmisi. Selepas itu, lapisan detail bukan langit akan bergabung semula dengan imej dehazed berdasarkan nada mengubah model. Imej yang dipulihkan akan diproses kemudian berdasarkan penyamaan histogram untuk meningkatkan kontras. Berdasarkan MSE dan PSNR ujian, kaedah DDE mendapat keputusan yang lebih baik dalam purata di mana nilai MSE adalah lebih rendah dan PSNR adalah lebih tinggi berbanding kaedah Gibson dan dark channel prior skim. Sebagai contoh, sampel imej 1 menunjukkan 17.1142 dB untuk skim dark channel prior, 15.0476 dB untuk kaedah Gibson dan 17.4007 dB untuk kaedah DDE dalam ujian PSNR itu. Berdasarkan ujian MSSIM, kaedah DDE menunjukkan struktur imej yang dipulihkan lebih berbeza dengan imej yang asal berbanding dengan teknik terdahulu. Secara keseluruhan, kaedah DDE yang dicadangkan dapat menghilangkan kesan jerebu dan meningkatkan butiran imej. Kaedah DDE juga mengatasi batasan kaedah Son, kelihatan yang gelap dan kesan blok atau halos.

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LIST OF SYMBOLS

I	Haze Image
D	Direct attenuation
a	Airlight
J	Haze free image
t	Transmission
A	Global atmospheric light
V	Atmospheric veil
β	Scattering coefficient
d	Depth
L_h	Surface radiance
L_r	Radiance of horizon
g	Optical setting of the imaging system
$\hat{D}$	Unit vector for direct attenuation
$\hat{a}$	Unit vector for airlight
P	Degree of polarization
$\mathrm{a}^{\max}$	Maximum airlight intensity
$\mathrm{a}^{\min}$	Minimum airlight intensity
$\hat{P}$	Unit vector for degree of polarization
$\hat{L}^{build}$	Unknown radiance
S^{build}	Slope of fitting line
l	Shading factor
R	Surface albedo coefficient
R'	Residual vector
I_a	Image along airlight vector
$I_{R'}$	Image along residual vector
C_Ω	Covariance function
J^c	Image with RGB colour channels
J^{dark}	Dark channel
$\Omega(x)$	Patch centred at x
ω	Constant used to maintain some haze effects
t_0	Lower bound of transmission
$\tilde{t}$	Rough transmission
$E(t)$	Soft matting function
I_i, I_j	Colours of the input image I at pixels i and j
δ_{ij}	Kronecker delta
μ_k	Mean matrix of the colors in window w_k
$\sum k$	Covariance matrix of the colors in window w_k
U_3	3x3 identity matrix
ε	Regularizing parameter.
L	Matting Laplacian matrix
R	Red channel
G	Green channel
B	Blue channel
H	Hue channel
S	Saturation channel
I	Intensity channel
c_i	Coarse volume

L	-	Search range
η	-	Constant
F	-	Iterative bilateral filter
G	-	Gaussian function
σ_s	-	Constant that used to control spatial weight
σ_r	-	Constant that used to control range weight
s_ω	-	Sum weight of local patch
q	-	Filter output
$\|w\|$	-	Number of pixels within the local window
p_i	-	Input filter
$\bar{p}_k$	-	Mean of input filter
μ_k	-	Mean of guidance image
σ_k^2	-	Variance of guidance image
ε	-	Regularization parameter
BF	-	Bilateral filter
O	-	Output image
w	-	Weight
c	-	Gaussian surround space constant
K	-	Constant for normalization of surround function
$l\alpha\beta$	-	Achromatic, chromatic yellow-blue and red-green opponent channels
σ_t	-	Standard deviation of target image
σ_s	-	Standard deviation of source image
I^{median}	-	Median filtered image
e_k	-	Error sequence
p_d	-	Control coefficient
e^2	-	Mean square error
$w_x,\ w_y$	-	Smoothness weights
h	-	Morphological grayscale reconstructed image
ε	-	Constant used to prevent the zero division
α	-	Constant used to determine the sensitivity to the gradients of h.
A_x, A_y	-	Diagonal matrices that containing w_x and w_y
D_x, D_y	-	Discrete differentiation operators,
B	-	Base layer
S	-	Sigmoid curve
g	-	gain coefficient
p	-	Predefined calibration factor
$\|I^m\|$	-	Total number of pixels in I^m
$\|d\|$	-	Total number of pixels in d
W	-	Brightest colour value
J_1^{dark}	-	Pixel based dark channel
J_1^{bright}	-	Pixel based bright channel
A_{max}^c	-	Brightest value in J_1^{dark}
A_{min}^c	-	Darkest value in J_1^{bright}
h	-	Kernel of APSF
AF^{cs}	-	Coarse image
AF^{rf}	-	Reference image

J_1^{median}	-	Pixel based median channel
I_{sharp}	-	Sharpened image
I_{smooth}	-	Smoothen image

LIST OF ABBREVIATIONS

APSF	-	Atmospheric Point Spread Function
BFLCC	-	Bilateral Filter in Local Contrast
DCP	-	Dark Channel Prior
DDE	-	Enhanced Detail & Dehaze
HSI	-	Hue, Saturation, Intensity
HSV	-	Hue, Saturation, Value
ICA	-	Independent Component Analysis
JND	-	Just-noticeable Distortion
MSE	-	Mean Square Error
MSR	-	Multi-scale Retinex
MSSIM	-	Mean Structural Similarity
PSNR	-	Peak Signal to Noise Ratio
RGB	-	Red, Green, Blue
SSIM	-	Structural Similarity
WLS	-	Weighted Least Square

CHAPTER 1

INTRODUCTION

1.1 Preface

Digital image processing is one of the growing fields in the computer graphics field because the quality of a digital image can be improved by the process of analyzing and manipulating the image. Many computer vision systems had been developed to work based on the input image. Therefore, the accuracy of the computer vision systems is highly depending on the input image quality. A high-quality image is needed so as to ensure the reliability of the computer vision systems by obtaining and providing more accurate information. In contrast, it is difficult to obtain and provide accurate information from a degraded or low-quality image.

A digital image can be referred as the combination of the direct attenuation and airlight. The direct attenuation refers to the scene radiance without the presence of the haze effects whereas the airlight is actually an ambient light that scattered towards the camera or the viewer (Schechner *et al.*, 2001). The image degradation problem is often caused by the existence of bad weather conditions such as haze and fog. Haze is formed by the aerosol particles which are smaller than the water droplets that formed the fog. Haze and fog can cause similar image degradation problem although both weather conditions are formed by different sizes of particles and it eventually leads to unclear images. Hence, the image degradation problem that caused by haze and fog has to be rectified in order to obtain high-quality images by restoring the visibility of the outdoor images.

Haze is a natural atmospheric phenomenon that consists of dust, smoke and other dry particles which will blur the view of a scene and continue to take its effects on an outdoor image. Therefore, the haze removal process is needed in order to enhance the image quality. Besides the image visibility restoration, the haze removal process also can recover the depth information which can be used for further or advanced image editing. An outdoor image that was degraded by the existence of the haze is shown in figure 1.1.

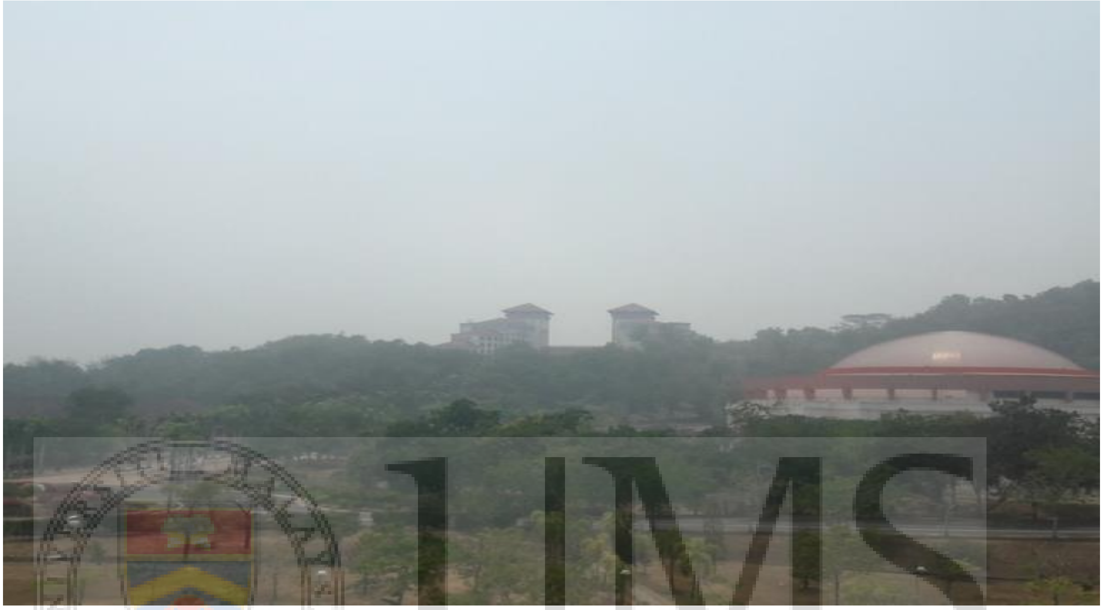


Figure 1.1 : Haze degraded image.

This research is conducted with the aim to remove the haze effects from a haze degraded image in order to enhance the image detail. There are many haze removal techniques as well as image detail enhancement techniques that had been proposed by researchers in the past. Among so many techniques, dark channel prior scheme and the Son method are selected to be studied in this research for both haze removal and image detail enhancement process. This is because dark channel prior scheme is simple and effective whereas the Son method is able to recover massive image detail. Both selected techniques will be modified and integrated together in order to achieve the objectives of this research. The details of the modifications and the integration of the techniques are described in the following chapters.

In this chapter, the research on the haze removal is introduced in section 1.1 whereas the problem background will be discussed in the next section. The problem statement will be stated in the following section. Section 1.4 and 1.5 cover respectively the aim and objectives of this research. The research scope is described in section 1.6 and the justification of this research is stated in the following section. The organization of this thesis is shown in the last section of this chapter.

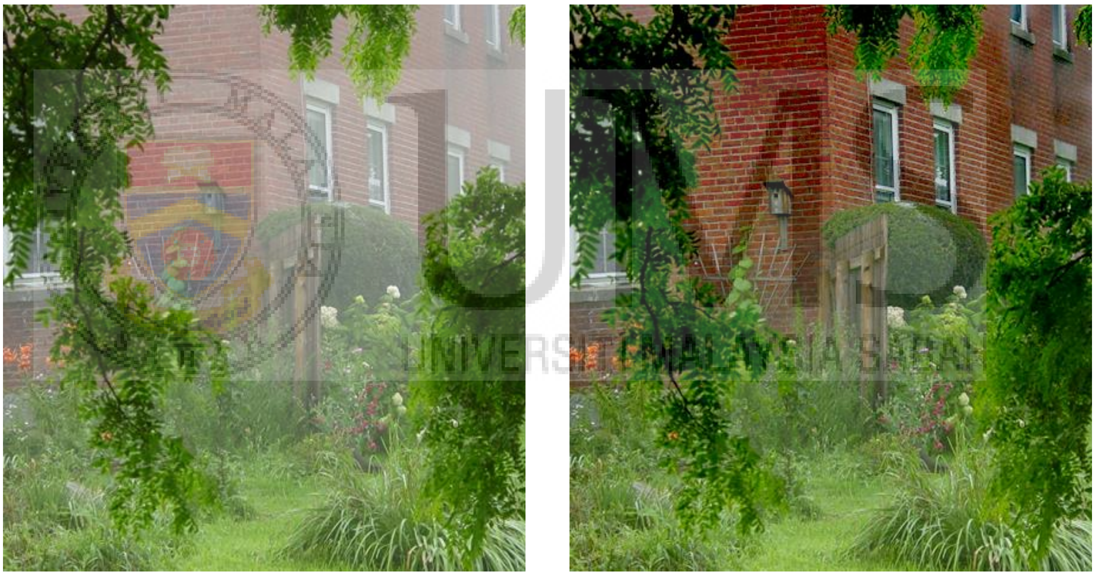
1.2 Problem Background

Many studies about the haze removal had been done in the past. The haze removal on the haze degraded image is quite challenging in the image processing field as the two variables, the transmission and the global atmospheric light, are unknown in the haze degraded image. Therefore, the finding of transmission and the global atmospheric light had become one of the main concerns in the study of haze removal.

Previous works on the haze removal can be categorized into multiple images haze removal technique and single image haze removal technique. The multiple images haze removal is the process of removing the haze effects from the haze degraded image by using multiple input images. However, multiple image haze removal technique is costly and additional information may be hard to be retrieved. On the other hand, the single image haze removal is the process of removing the haze effects from the haze degraded image by using single input image. Single image haze removal technique is simpler and effective if compared to the multiple images haze removal techniques.

Among the previous researches that had been done on the multiple images haze removal, there were weather condition based techniques (Nayar and Narasimhan, 1999) and polarization-based techniques (Schechner *et al.*, 2001). The weather condition based technique had been proposed with the introduction of a dichromatic atmospheric scattering model. Besides, the weather condition based techniques required multiple images with the same scene view but taken under different weather conditions as the input for the haze removal process. These techniques were definitely costly and the recovered images after the haze removal process cannot be obtained immediately. Furthermore, the weather condition based techniques are not suitable to be used for the haze removal on the dynamic scenes due to the change of weather conditions is required for the haze removal process.

Next, the polarization-based technique had been proposed in order to remove the haze effects from the haze degraded image based on the fact that the scattered airlight was partially polarized. The polarization-based technique was the multiple images haze removal technique that required two independent polarized images that had been taken at different orientations as the input for the haze removal process. The polarization-based technique can work instantly and it does not rely on the change of weather conditions. In addition, a blind estimation technique (Shwartz *et al.*, 2006) had been proposed for the polarization-based technique in order to separate the airlight from the direct attenuation.

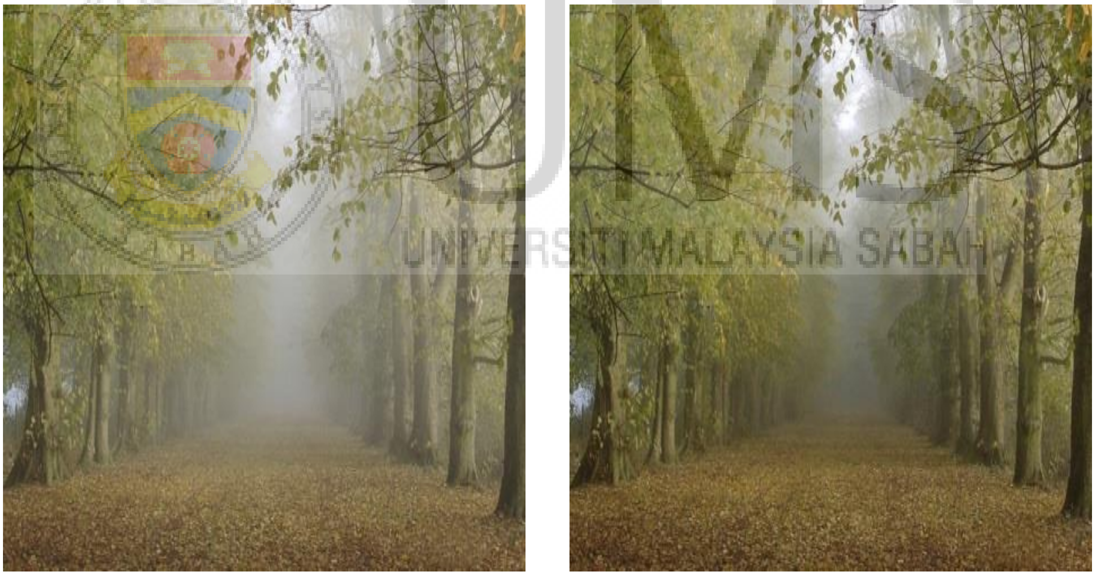


(a) (b)

Figure 1.2: The haze removal using Fattal technique. (a) Original image (b) Recovered image.

Among the previous works on the single image haze removal, many proposed techniques were prior based developed techniques where the success of the haze removal process is dependent with the prior. The first attempt of the prior based single image haze removal technique was the Fattal technique (Fattal, 2008) that had been proposed based on the Independent Component Analysis (ICA). The ICA was an assumption that the image shading and the transmission were independent with each other. In addition, the ICA-based technique was very useful for the airlight reduction and the restoration of image contrast. Figure 1.2 shows the haze removal using the Fattal technique based on the Independent Component Analysis (ICA).

After that, a simple but very effective prior, the dark channel prior (He *et al.*, 2009) had been proposed as the assumption that most of the non-sky local patches in the haze-free outdoor images will contain many dark pixels. The dark pixels were also known as the pixels that had very low intensities in at least one color channel. The introduction of the dark channel prior had been considered as one of the landmarks in the history of haze removal as the dark channel prior scheme had a very good achievement in the haze removal. Many researchers had selected the dark channel prior scheme as the foundation of their studies on the haze removal process.



(a) (b)

Figure 1.3 : The haze removal using dark channel prior scheme. (a) Original image. (b) Recovered image.

However, the haze removal using dark channel prior scheme also had several problems such as dark look, loss of detail, oversaturation, time complexity and the existence of the block or halo effects. These problems mostly occurred due to the transmission estimation was not much accurate as the transmission was not