# ENHANCED DARK CHANNEL PRIOR AND TRANSMISSION MAP ESTIMATION TECHNIQUES FOR REMOVING FOREGROUND DENSE HAZE ON STATIC IMAGE

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IJAZAH: **SARJANA SAINS (MATEMATIK DENGAN GRAFIK BERKOMPUTER)**

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# DECLARATION

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

23 MARCH 2018

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# CERTIFICATION

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## CERTIFIED BY

**1. SUPERVISOR**

Assoc. Prof. Dr. Abdullah Bade

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# ABSTRACT

Haze removal on a degraded image was the challenging task in image processing field. A reliable technique must be able to remove dense haze effects on the static image, in addition, improving the quality of the image. Hence, this research proposes the integration between the two enhanced techniques for dense haze effects restoration at the foreground of outdoor scenery image. For the first technique of modified dark channel prior allows it to remove haze, which improves of contrast quality and obtains the haze intensity. The intensity of dark channel allows estimation of the thickness value of haze. Additionally the second technique, transmission map estimation, was modified to improve the image colour quality and its details. Both of these techniques will be integrated to form a full process of dehazing technique. The restored image then proceeds to the post-processing stage for contrast enhancement and gamma correction. Histogram equalization technique is used for contrast enhancement and gamma correction is used for colour correction of image, with improved brightness. Besides that, the median filter is applied for transmission refinement and to improve edges on the image scene. Several tests were implemented in order to validate the results of this experiment. For example, the Mean Square Error (MSE) test and Peak Signal to Noise Ratio (PSNR) test were used for the image quality assessment. The obtained test values show that the proposed technique achieved better results with lower values for MSE and higher values for PSNR compared to the other established haze removal techniques in the field of image enhancement; Kaiming and Gibson techniques. The MSE test value for the proposed technique was only 2009.76dB, meanwhile, Kaiming and Gibson techniques showed 3920.13dB and 2785.07dB respectively and the PSNR test value was 15.13dB, however, both of Kaiming and Gibson techniques recorded 12.23dB and 13.72dB respectively which further proves that the proposed technique produces a better image. Finally, a test of Structural Similarity Index (SSIM) will be taken in order to show that the output scene of haze-free image was not similar to the input scene of hazy image. In general, the proposed technique is able to remove the foreground dense haze from the outdoor scenery static images and at the same time improves the contrast and colour quality on-scene image.

# *ABSTRAK*

## *PENAMBAHBAIKAN GABUNGAN TEKNIK-TEKNIK DARI DARK CHANNEL PRIOR DAN TRANSMISSION MAP ESTIMATION UNTUK PEMBUANGAN JEREBU PADAT PADA LATAR DEPAN IMEJ STATIK*

*Penghapusan jerebu pada imej yang terdegradasi adalah merupakan tugas yang mencabar dalam bidang penyelidikan pemprosesan imej. Oleh itu, hanya ada beberapa teknik sahaja yang mampu untuk menghapuskan kesan jerebu padat pada imej latar depan, disamping dapat meningkatkan kualiti imej. Kajian ini mencadangkan proses integrasi di antara dua teknik yang telah dipertingkatkan untuk membaikpulih kesan jerebu padat yang merosakkan pemandangan pada latar depan imej statik. Teknik yang pertama, iaitu teknik dark channel prior yang telah diubahsuai akan mempertingkatkan kualiti kontras serta untuk memperoleh intensiti jerebu. Intensiti dark channel prior mampu untuk menganggarkan nilai ketebalan jerebu. Diikuti pula teknik yang kedua, pengubahsuaian teknik transmission map estimation adalah untuk meningkatkan kualiti warna imej serta butiran-butiran pada imej. Kedua-dua teknik ini akan diintegrasikan untuk membentuk satu proses penuh teknik dehazing. Di samping itu, penapis median akan digunakan untuk penambahbaikan transmission dan untuk meningkatkan butiran pada adegan imej. Imej yang telah dipulihkan akan ke fasa post-processing, untuk peningkatan kontras dan pembetulan gamma. Teknik histogram equalization akan digunakan sebagai penambahbaikan kontras serta untuk menyesuaikan intensiti pada imej, sementara itu, pembetulan gamma adalah untuk membaikpulih warna pada imej, serta untuk kecerahan yang lebih baik. Terdapat beberapa ujian yang akan dilaksanakan untuk mengesahkan hasil terbaik daripada eksperimen ini. Contohnya adalah ujian Mean Square Error (MSE) dan ujian Peak Signal to Noise Ratio (PSNR) yang akan dilaksanakan untuk penilaian kualiti imej. Nilai ujian yang diperolehi menunjukkan bahawa teknik yang dicadangkan ini mampu menghasilkan keputusan yang baik berbanding teknik lain dalam bidang image enhancement iaitu teknik Kaiming dan teknik Gibson. Nilai yang lebih rendah untuk MSE dan juga nilai yang lebih tinggi untuk PSNR adalah contoh keputusan yang baik. Nilai ujian MSE untuk teknik ini menujukkan hanya 2009.76dB, manakala teknik Kaiming dan Gibson masing-masing menunjukkan 3920.13dB dan 2785.07dB. Sementara itu, nilai ujian PSNR menunjukkan 15.13dB, bagaimanapun, teknik Kaiming dan Gibson masing-masing mencatatkan 12.23dB dan 13.72dB. Akhir sekali, ujian Structural Similarity Index (SSIM) pula menunjukkan bahawa pemandangan pada output imej tanpa jerebu adalah tidak sama jika dibandingan dengan pemandangan pada input imej yang berjerebu. Secara umumnya, teknik yang dicadangkan ini dapat menghilangkan jerebu padat pada latar depan imej dan pada masa yang sama dapat meningkatkan kualiti kontras dan warna pada pemandangan dalam imej.*

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| | | |
|---|---|---|
| $H$ | - | Hazy Image with Observed Intensity Colour |
| $c$ | - | RGB colour channels |
| $F$ | - | Haze-Free Image |
| $p$ | - | Represented as pixels of x and y (for hazy image) |
| $q$ | - | Pixels of Dark Channel |
| $t(p)$ | - | Transmission Map |
| $F(p)t(p)$ | - | Direct Attenuation |
| $A(1-t(x,y))$ | - | Airlight |
| $A$ | - | Global Atmospheric Light |
| $(x,y)$ | - | Pixels at its location on the image |
| $O_3$ | - | Ozone |
| $CO$ | - | Carbon Monoxide |
| $NO_2$ | - | Nitrogen Dioxide ($NO_2$) |
| $SO_2$ | - | Sulphur Dioxide ($SO_2$) |

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| **DCP** | - | Dark Channel Prior |
| **HSI** | - | Hue, Saturation, Intensity |
| **RGB** | - | Red, Green, Blue |
| **MSE** | - | Mean Squared Error |
| **PNSR** | - | Peak Signal to Noise Ratio |
| **SSIM** | - | Structural Similarity Index |
| **API** | - | Air Pollutant Index |
| **PSI** | - | Pollutant Standards Index |
| **BSHTI** | - | Background Suppressed Haze Thickness Index |
| **VCP** | - | Virtual Cloud Point |
| **HTM** | - | Haze Thicknesses Map |
| **MAAGs** | - | Malaysian Air Quality Guidelines |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

In the era of technology, image processing field is influencing many aspects of our daily life. For example, image processing is applied in the medical field (interpretation of X-ray images) and in robot vision. Recently, many researchers have studied image processing. A digital image can be manipulated based on the various image processing techniques such as restoration, colour correction, sharpness adjustment and contrast enhancement to create a better quality of image. The original image is taken as the input data, and mathematical operations can be applied to the image for manipulating the output results.

Malaysia has developed its economy by expanding the industries, which can lead to heavy pollution especially air pollution. This kind of air pollution causes bad weather, such as haze. Dense haze always affects the quality of outdoor photography images. This will be the most annoying problem faced by photographers. This case would lead problems to many applications in computer vision. However, the quality of images can be improved by using image processing method. The example of an outdoor scenery image was taken during dense haze, which is shown in Figure 1.1.

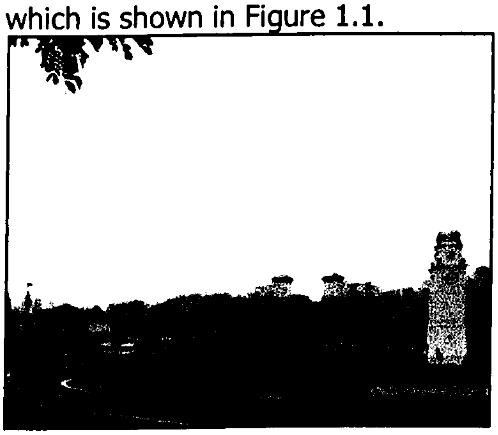


**Figure 1.1: Example of Hazy Image**

The presence of haze in the atmospheric area will disturb the observation of real scenes due to the loss of visibility and contrast on image, which makes the images appear unclear (Lv *et al.*, 2010). The haze that is scattered on the image will be analysed by several potential methods, which is discussed throughout this thesis. Hence, a suitable, improved method by the means of image processing will be implemented in order to restore the hazy image. The improved algorithm of haze removal is based on the estimation of haze thickness. It becomes more difficult to remove haze on image when the haze is dense.

Besides that, the quality of haze-free images depends on noise reduction and error that is scattered on the images. In the future, this research might be adapted for the development of mobile applications on Android and iOS platforms to realise the motivation of this research. This is because previous developers have done the applications of haze removal on mobile for static image. However, they need efficient algorithms to detect dark pixels and use its value to calculate the transmission for estimating the value of nearby pixels (Chiang, 2013). Therefore, this thesis will improve the techniques mentioned in previous studies to restore images affected by haze.

## 1.2 Problem Background

The main concern of this research is to improve the performance of haze removal technique for the outdoor scenery static image. Many drawbacks occur during the process of haze removal. In the image processing field, haze removal process is the most challenging process due to the unknown scene of depth information on image. This problem has occurred on the classical approaches of haze removal. The classical approaches are known as multiple images haze removal and additional information haze removal. Both of these techniques might be costly due to many requirements needed and extra hardware device for the dehazing process, in order to gain the accurate of depth information on image. If there is only a single input of hazy image during the dehaze process, the experiment might be inaccurate due to the lack of information.

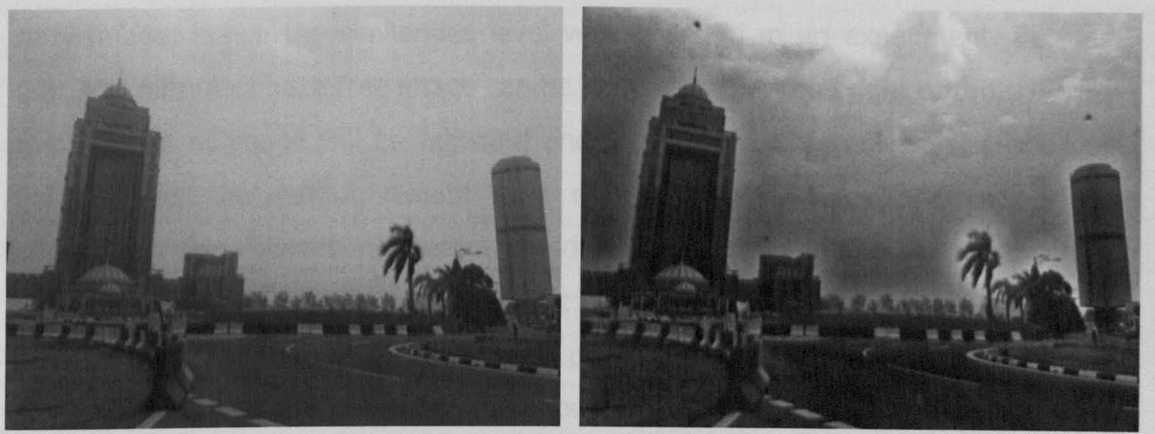
In order to reduce this problem, a technique of single image haze removal has been proposed. It can also deliver with faster execution compared to the classical approaches. This is because it requires only a single input of hazy image. A single input of hazy image is enough to produce the output results. Since then, many researchers carry out their study regarding a single input of image without any additional requirements.

The type of input image plays an important role in order to ease the process of haze removal. Obtaining input of static image is the easiest compared to video. The captured video sequences need to provide an input, and then the system will process it into several frames (Alajarmeh *et al.,* 2014). The input of grayscale image cannot achieve satisfying results as its colour information of RGB channel on image is the basic source from a dark channel prior based techniques (J. Li *et al.,* 2015). The type of weather also affects the experiment process. Resolving of steady weather problems, such as haze, is the easiest to be processed compared to dynamic weather, like rain. It is due to the haze that has very small particles size in the atmosphere; meanwhile, the size and velocity of the rain streak are larger than haze. If the size of rain particles is smaller, then only some techniques for solving haze problem can also be applied for rain. However, if the size of rain particles are larger, then the problem will occur when the techniques are applied for haze. The larger the size of rain streak will cause the other techniques and statistical characteristic may be applied (Wahab *et al.,* 2013).

Apart from that, haze weather can cause many drawbacks on the input of hazy image. It includes the change in colour scenes and it can also diminish the view of the scenes (Kurian, 2014). Besides that, the contrast of image is reduced due to the scattering of light towards a camera, where it is also caused by attenuation (Inampudi *et al.,* 2002). In addition, the input of degraded image obtains with very low intensity. Therefore, an adaptive gamma correction technique will be applied in order to adjust the intensity of the transmission map. A well-known algorithm of transmission map estimation works for three colour channels randomly. It is derived from the dark channel prior algorithm. Transmission of haze occurs when the light passes through objects on the scene. Haze also can increase the whiteness on image. The whiteness in the scene image is caused by airlight. The image is also degraded due to the loss of high-frequency components, which can lead to scene blurring (Cho *et al.,* 2013).

The haze removal research grows tremendously as there are many issues occurring in this field. One of the biggest issues in haze removal is to remove dense haze on outdoor scenery static image. By focusing on this issue is to ensure that the image quality will improve. Some of the haze removal techniques may fail in some extreme cases especially in the case of dense haze. For example, a method that estimates the optical transmission in hazy scenes cannot remove haze when the haze is too thick, and it frequently exhibits overstretched contrast. It is due to the incorrect estimation of scene depths (Fattal, 2008). Accordingly, a dark channel prior technique is suitable for dense haze because the intensity of dark channel allows approximating the thickness value of haze. Besides that, this technique allows detecting the most haze-opaque region on the input of hazy image (C. H. Yeh *et al.,* 2012).

Based on the previous technique of dark channel prior by Kaiming, it allows restoring high quality of haze-free image and it can directly estimate the haze thickness on image. However, dark channel prior is known as a statistic, where it cannot perform very well for some particular of images especially for the image that scattered with dynamic weather. Besides that, the output results might contain with few of halo effects (He *et al.,* 2011). Figure 1.2 shows the example of images that resulting in halo effects. The output result in Figure 1.2(b) shows the halo effects that can be seen around the building and trees.



(a) (b)

**Figure 1.2: Haze Removal Using Dark Channel Prior by Kaiming. (a) Original Hazy Image, (b) Haze-Free Image with Halo Effects**

Apart from that, one of the factors that can lead to halo effects on image is when the transmission map estimation occurs incorrectly. It also delivers problems such as false textures and blocking artifacts. In order to overcome the problem of halo effects and unsatisfactory estimation of transmission map, a median filter will be applied. The median filter also can improve the edges information on image (Huang *et al.,* 2014).

Gamma correction can be worst on the certain image until it provides with bleached out or too dark of output image. Therefore, apply the contrast enhancement that can improve the quality of image based on its statistic, such as histogram equalization in order to balance the colour image (Gibson *et al.,* 2010). Both of these techniques can be obtained as tone mapping techniques (Fattal, 2008). However, histogram equalization generates a saturated of output image.

Based on the problems that have been discussed in this section, the technique of haze removal will be improved in order to restore dense haze image.

## 1.3 Problem Statement

The main problem of haze removal technique is to handle the case of dense haze with special attention to improve the quality foreground scene of hazy image. Apart from that, this research is mainly concerned with improving the performance of the image quality. The quality of the image depends on the amount of noise and error, where the output results will be compared with the previous research through experiment. The results of haze-free image cannot be the same as the original of hazy image, hence the similarities level will be tested in an experiment. Besides that, the output of haze-free image can be oversaturated, too bright or too dark, so the contrast of image will be adjusted and the colour corrections will be applied. Furthermore, the output results may contain halo artifacts and the edges information were blurred. Therefore, the details of image will need to be restored. In recent times, many techniques of haze removal have been proposed. One of them is to enhance by using dark channel prior as its base. The enhanced approach of dark channel prior will be then recomputed the transmission map estimation in order to perform a better of haze removal process.

## 1.4 Research Aim

The aim of this research is to restore the degraded outdoor scenery static image from the dense haze, provide with better quality results while at the same time able to remove haze at foreground scene by integrating the modified dark channel prior technique and enhanced transmission map estimation technique.

## 1.5 Research Objectives

In order to achieve the research aim, the objectives of this research are listed as followed:

i. To improve the algorithm of dark channel prior in order to restore the contrast quality of hazy image.

ii. To modify the transmission map estimation algorithm in attempt to restore the colour of image and details.

iii. To integrate the two enhanced techniques of dark channel prior and transmission map estimation in order to remove dense haze effect on the outdoor scenery static image, which results in a better quality of haze-free foreground image.

## 1.6 Research Scope

Generally, this research is mainly focusing to enhance dense haze removal technique for a single image. Image processing operations will be applied in order to form a complete haze removal technique. The setup of haze removal experiment should be well prepared throughout this project. For further explanations, it will be discussed in Chapter 3. However, a brief of the research scopes will be listed as below:

i. The input of outdoor scenery static image that degraded by dense haze will be restored in order to generate the output of haze-free foreground image.

ii. The technique of dark channel prior, which is for contrast quality on dense haze will be modified in this research.

iii. The technique of transmission map estimation, which are for colour channels improvement and details image will be modified in this research.

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