CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

This thesis design and analysis are the combined performance of single sensor digital camera image pipeline flow. It proposes an improved unified spatial chromatic sampling framework for Color Filter Array (CFA) for single sensor digital camera with Edge preserve non threshold demosaicing algorithm.

Image Enhancement is a dominant research area in image processing. In that demosaicing of Color Filter Array images is very important in the Camera Image pipelining process. The color values from the illuminated object sensed by Color Filter Array, it will allow only portion of light from electromagnetic visible spectrum (Gunturk et al. 2002). Michael & Joel Trussell (1993) describes that the overall single sensor camera system spectral sensitivity is obtained by careful selection of the color filters and imaging illuminant. The problem of proper selection of color filters and imaging illuminant can be modeled as an optimisation problem. Lukac & Plataniotis (2005) proposed many CFA pattern, the basic standard CFA pattern is Bayer RGB pattern which is widely used. The accuracy of the single sensor camera device output increases by increasing the sampling of different colors. The different types of sampling patterns are available commercially and some of them are used by different camera manufacturers. Michael & Joel Trussell (1994) presented that Single Sensor Camera accuracy of color
acquisition devices is increased to a large extent by sampling an bigger number of different color channels. The extraction of three channel colors such as Red, Green and Blue from mosaiced raw image data is called Demosaicing. When we capture a scene using single sensor CCD or CMOS camera, Demosaicing problem arises. The extraction of good quality image from CFA with color artifact is a challenging task. The color artifacts like Edge blurring, Zipper Effect, Aliasing and False coloring are the major artifacts (noise) that arise at the time of Demosaicing. In the CFA interpolation the different colors such as Red, Green, Blue, Yellow and Cyan are estimated by different interpolation techniques.

1.1.1 Architecture of Digital Camera

In digital cameras, the color information of a real-world scene is acquired through an image camera sensor, usually a Charge-Coupled Device (CCD) (Turko & Yates 1989) or Complementary Metal Oxide Semiconductor (CMOS) sensor (Blanksby & Loinaz 2000) in the format of superimposition of three primary color channels, Red(R), Green(G), and Blue(B). Commonly used image sensors are monochromatic devices that sense the light within limited frequency range, and therefore cannot acquire color information directly. The digital camera and PDA with camera making companies use several strategies or approaches followed to capture the scene which is to be in color nature because the image sensor may be form of Monochromatic nature. The most straightforward approach to capture a digital image is to use three separate sensors to capture RGB light. A beam splitter is used to project the light through three color filters, and towards three sensors. However, a sensor is one of the most expensive components of a digital camera, usually taking upto 25 percent of the total production costs (Adams et al. 1990), and thus, the three-sensor method is only used for high-end professional cameras. The cost effective alternative to the three-sensor approach is a single-sensor imaging technology. To minimize Complexity and cost, the majority of digital
cameras are equipped with a sensor coupled with a Color Filter Array (CFA). A CFA is a mosaic pattern of color filters placed on the top of CMOS/CCD image sensor to filter out single color channel from components like R, G, and B in each pixel position. Consequently, a digital image acquired by CFA, called a raw CFA image, stores only a single measurement of RGB in each pixel and missing components are regenerated through a color demosaicing (CDM) process, also known as a CFA interpolation (Plataniotis & Venetsanopoulos 2000). Typical Digital camera Architecture is shown in Figure 1.1. The input scene (Problem Domain) is sampled by CFA filter sensor and quantized and encoded by Application Specific DSP processor and gives the digital output image representation. The image processing steps such as noise removal, red-eye removal are processed by General purpose processor. Audio codec will perform audio signal processing for the captured video. Display image, sharing of image editing all performed by main processor.

(Source : Plataniotis & Venetsanopoulos 2000)

Figure 1.1 Digital Camera Architecture
1.1.2 Types of Digital Camera

There are two types of digital camera technologies used for acquiring image using image capturing devices. They are (i) Three-Sensor Array Camera and (ii) Single-Sensor Array Camera.

1.1.2.1 Three-sensor array camera

In three-sensor digital color camera system the light entering into the camera lens is split into three color beams by a beam splitter. The spitted beams then projected on to the corresponding optical paths having color filter such as Red, Green and Blue with each filters having different spectral transmittances to fall on its spectral sensor such as CCD or CMOS sensor (Kenneth & Parulsk 1985). A portion of the electro-magnetic wave in the visible spectrum absorbed by pigments in color filter arrays while passing the rest to the photosensitive devices underneath the filter. Figure 1.2 shows the block diagram for three sensor camera.

(Source : Sharma & Trussell 1997)

Figure 1.2 Three-Sensor Array Digital Camera
In optical path sensor only responds to one of the primary colors (Red or Green or Blue) filtered out by the respective color filter in CFA and optical path contains the same visual information. In camera sensor requires its proper carrying electronics in photodiode, and the image sensors have to be arranged precisely. The resultant of each optical path in camera is a monochromatic (gray scale) image. The full color image is obtained by combining the three monochromatic images specifically (Sharma & Trussell 1997).

1.1.2.2 Single-sensor array camera

Single sensor cameras are highly economical compared with electronic commercial color cameras employing three separate sensors (e.g., red, green and blue sensors). Single sensor cameras which record only one of the three colors (r, g, b) at a pixel location. Using a since sensor array of a camera accounts substantial part of the total cost of the camera (Jim 1998). Single sensor Color image produced in a image sensor (CCD imager integrated circuit or CMOS) signal simply by imposing a color filter array above the sensor. Image capturing process illustration is shown in Figure 1.3.

(Source : Lyon 2000)

Figure 1.3 Single-Sensor Array Digital Camera
The different colors from the reflected source of illuminant impinge on CFA in fixed predefined pattern of array elements or pixels. In the three color image green channel related to the luminance component and other two channels such as red and blue related to the chrominance component of an image.

The single sensor camera the image resolution getting reduced, because of one color information is gathered at time and missing other color components. The missing color components can be retrieved by interpolation or demosaicing processes. Because of the interpolation processes the visible distortions can be reproduced. Luminous component was more sensitive to human eye if there will be distortion it may reflected.

In order to reduce the distortion perceived in human visual system and give good perceived image the pixel density of green or luminance channel should be increased than that of chrominance signal. So in practical CFA made with more number of Green filters (luminance) and remaining pixel associated with Red and Blue (chrominance)

1.1.3 CFA Pattern

There are different types of CFA patterns normally used in single sensor cameras. In general there are two classes of CFA patterns,

i. Periodic CFA pattern (Regular arrays)

ii. Non-periodic CFA Patterns (Irregular arrays)

1.1.3.1 Periodic CFA pattern

The main highlighted importance of periodic CFA pattern is it is less immune to optical and electrical cross-talk with other pixel in the CFA
pattern. In general the quality of the CFA pattern affected by cross talk or leakage with neighboring pixel that may lead to change in spectral transmittance function. Consistency should be maintained in periodic CFA with neighboring pixel to increase spectral transmittance function.

Moiré artifact may affect the regular periodic CFA pattern because of same frequency structure repeatedly available in CFA image.

1.1.3.2 **Bayer RGB pattern**

Bayer RGB pattern was invented by Bryce E Bayer in 1976. It is one of the universally accepted pattern and used in almost all cameras. In a 2x2 CFA pattern green channel is sensed twice than other two color channel such Red and Blue pixel. However green channel is more sensitive for human eyes so more number of green channels used than other channels. The Bayers RGB CFA pattern representation shown in Figure 1.4.

![Figure 1.4 Bayer RGB CFA Pattern](image)

1.1.3.3 **Bayer CMY pattern**

Due to the problem with sensor manufacturing issues and color fidelity Only the RGB pattern has been employed initially. However the CMY
(Cyan-Magenta-Yellow) pattern shown in Figure 1.5, has much better quantum efficiency and spectral response. CMY-based patterns have, in fact, been used in the video world for years. Now, because of the better development and advancements in sensor design and a better understanding of system noise sources, CMY filter pattern has become possible, bringing important advantages to the camera designer.

![Figure 1.5 Bayer CMY CFA Pattern](image)

The major advantage of the CMY-based filter array is sensitivity. In photographic terms, this sensitivity results in superior performance across a wide range of light exposures (ISO ratings). The advance made is the result of two main attributes of the CMY CFA: better light transmission and a stronger color signal.

In CMY-based CFA the advantages is better transmission to less light absorption by the color dyes than with an RGB based scheme. In an RGB CFA system, each color is created by applying two layers of dye. The arrangement consists of one layer of yellow and one layer of magenta for red channel, one layer of yellow and one layer of cyan for green channel, and one layer of magenta and one layer of cyan for blue channel. Only one dye color required for each basic color used in CMY CFA.
Color filter dyes placed in camera are practically not 100-percent efficient. Ideally, they would let the light of one particular color pass through and completely absorb the light of the other colors. But in reality, they also have a tendency to absorb some of the colors they intended to pass. Since the unwanted absorption effect is present in single sensor camera is additive, this leads to reducing the amount of light transmitted through to the sensor when compared to a CMY system.

### 1.1.3.4 RGBE filter

RGBE filter is an alternative version of Bayer RGB CFA pattern. Mosaic pattern of RGBE filter consists of four colors such as Emerald (Cyan), Red, Green and Blue and its demosaicing full color image pattern shown in figure 1.6. It was developed by Sony and so far is used only in the ICX456 8-megapixel CCD and in the Sony Cyber-shot DSC-F828 camera. Sony camera makers use this pattern. The reason for adding the fourth filter color is to record the natural image as duplicate of original and mitigate the reproduction color errors and human visual perception with good clarity.
1.1.3.5 CYGM filter

In CYGM filter pattern consists of four colors such as cyan, yellow, green and magenta. This pattern is alternative to the previously explained RGBE filter pattern it also requires demosaicing to filter out the full color image.

CYGM filter pattern image is having high dynamic range and more accurate luminance (Green pixel) information than that of Bayer RGB pattern. It is because of cyan and yellow components of the color filter array do not produce a true monochromatic cyan/yellow but are rather modifications of the filters used to absorb 'color'.

![CYGM Filter Diagram](image)

**Figure 1.7 CYGM Filter**

In general color theory explains, a green channel pixel value is taken by arranging a color filter in front of the light sensor that absorbs red and blue. A blue channel pixel is taken with a green and red filter, and a red channel pixel value with a blue and green filter. Therefore in RGB CFA pattern derived by using two color filters for each color channel measurement. So that in practical situation some of the light that falls upon the sensor array is absorbed by the filters (normally it arranged to absorb light within a electromagnetic spectrum range of wavelengths). The main difference between CYGM color filter array and the standard Bayer filter by using only
a single color filter is that it uses three of the four sensors. Therefore it may produces a broad spectral response and it leads to measurements more accurate in respect to luminance but it is difficult to measure color information accurately. So that green is unaffected (produced with 2 color filters), the color accuracy difference arises from the fact that the red and blue sensors (as seen in Bayer CFA filter) are in effect changes into magenta and cyan sensors.

1.1.3.6 Kodak RGBW filter

Alternative to the Bayer filter in June 14, 2007, Eastman Kodak invented new CFA pattern called RGBW. In camera filter pattern light sensitivity of the image sensor increased by using some panchromatic cells that are sensitive to all band spectrum of visible light and collect a larger amount of light striking the sensor. They have introduced many number of patterns, but none with a repeating unit as small as the Bayer pattern's 2×2 unit shown in Figure 1.8.

![Figure 1.8 Kodak RGBW Filter Patterns](image-url)
1.1.3.7 X-trans CMOS sensor

![Figure 1.9 Fujifilm X-Trans CMOS Sensor](image)

The Fujifilm developed X-Trans CMOS CFA pattern, it used in many Fujifilm X-series cameras. The main advantage is to provide better resistance to color moiré than the Bayer filter, and as such they can be made without an anti-aliasing filter shown in Figure 1.9. Because of this advantage allows cameras using the sensor to achieve a bigger resolution with the same megapixel count. This new design CFA pattern is aimed to reduce the incidence of false colors, with red, blue and green pixels in each line. The non-periodic pattern arrangement of these pixels sensor is also said to provide grain more like film.

1.1.3.8 Other periodic CFA patterns

The Examples of the other CFAs such as Yamanaka, Lukac, Diagonal Striped, Striped and CFA based upon the Holladay halftone pattern are shown in Figure 1.10 (a) to (c) and (e). Each pattern has its own properties based on its color channel components.
Figure 1.10 Examples of the other CFAs (a) Yamanaka (b) Lukac (c) Diagonal Striped (d) Striped (e) CFA based upon the Holladay halftone pattern

The CFA using alternate vertical stripes shown in Figure 1.10 (d) of the RGB primaries has been released first, since it is well suited to the interlaced television video signal.

1.1.3.9 Non-periodic CFA pattern

Irregular or Non-periodic CFA pattern mitigate the problem associated with periodic or regular pattern. Along the columns of sensor array, fixed pattern noise present. Noise present in regular patterns are mitigated by irregular or random colors filter array.

The accuracy of camera generally increased by taking more number of sample taken by more number of colors in CFA. Using Fixed number of neighbours with respect to Red or Blue or Green pixel electrical/optical immunity power can by increased. So that it is observed that diagonally
located neighbours have a lower cross-talk contribution than the vertically or horizontally placed neighbour channels.

Camera manufactures select the CFA based on the type of optical system of camera, resolution specification, digital image processing capabilities of camera and some specific application. This may cause no proper correlation because no CFA cope up with all condition. Once CFA sensor layout was selected the quality of demosaiced full-color image depends on capability of demosaicing algorithm with the spatial, spectral and structural correlation.

The pseudo-random filter array is shown in Figure 1.11, has been inspired by the human eye physiology, in an attempt to reproduce the spatial repartition of the three cone cell types on the retina surface (Lukac & Plataniotis 2005). Its irregularity achieves a compromise between the sensitivity to spatial variations of luminance in the observed scene (visual acuity) and the ability to perceive thin objects with different colors. Indeed, optimal visual acuity would require photo-sensors with identical spectral sensitivities which are constant over the spectrum, whereas the human visual perception of thin color objects is improved with sufficient local density of different types of cones in eye.

![Figure 1.11 Examples of Non-periodic CFA Patterns](image-url)
1.1.4 Spectral Response Chart

The Spectral Response chart is shown below in Figure 1.12, it compares the efficiency and operating range of sensors using RGB and CMY schemes. Two issues become evident when comparing, for example, the green response of an RGB system with the yellow response of a CMY system. First, the yellow signal has much higher amplitude (Y axis) than the green signal: approximately 45% vs about 28% for green. This variation occurs because of the reduction in unwanted absorption of light energy. Second, the yellow in a CMY system is responsive to a much broader range of wavelengths (X axis) than the green in an RGB system. It gives rise to greater than 10% efficiency, for example, wavelength from a 500-nm to beyond 750-nm wavelength, while green has a far narrower in wavelength region 500- to 600-nm range of frequencies.

Figure 1.12 Spectral Response chart
To shine a light source with constant energy at all wavelengths onto a sensor, the yellow signal of a CMY system would be about twice as large as the green signal of an RGB system, providing higher effective ISO. That is, it can successfully create image over a wider range of exposure levels. The noise in the fundamental sensor is constant for both type of CFA system, the CMY patterns provides larger SNR which, leads to increases the sensor's ISO range.

1.1.5 Introduction to Demosaicing

In a single sensor camera system one color information filtered at time in a pixel location. Demosaicing algorithm is used to extract missing color information from mosaiced raw filter data. The process of extraction of missing two other color data from a single sensor camera is known as demosaicing (interpolation). The demosaicing algorithm the processing computational complexity should be low.

In general there are two types of demosaicing algorithms it can be classified as adaptive and non-adaptive algorithms

1.1.5.1 Non-adaptive demosaicing algorithms

Non-adaptive algorithm average the pixel in random manner. It perform demosaicing in a fixed patter of pixels. Due to this causes artifact called Zipper effect in demosaiced image.

The examples of famous non-adaptive algorithms are listed below,

(a) Nearest Neighbourhood Interpolation (Zen 1998)
(b) Bilinear Interpolation (Sakamoto et al. 1998)
(c) Smooth Hue Transition (Cok 1987)
(d) Median Based Interpolation (Freeman & William 1988)
1.1.5.2 Adaptive demosaicing

In Adaptive demosaicing algorithms the missing pixel is very close to the neighboring pixel, and it is having spatial and spectral features is very near to neighbours. Similar to Image processing domain other algorithmic problems the correlation and model design are the very vital role in demosaicing process (Nai-Xiang et al. 2007). Most of the color channels will have same characteristics such as texture and edge of the image with other channel (Plataniotis & Venetsanopoulos 2000). If ignore the interplane dependency between channels the demosaiced image flags artifacts (Plataniotis & Venetsanopoulos 2000). To yield good quality demosaiced image quality of demosaicing algorithm plays vital role. The sophisticated demosaicing algorithm will use spatial and spectral correlations (Plataniotis & Venetsanopoulos 2000). Different kinds of technique were adopted to achieve quality demosaicing using inter-plane correlation. The challenge raised here is quality of image and cost of computation.

It uses neighborhood pixel to detect spatial features in adaptive algorithms, and then build useful choices as to which predictor to use for that neighbourhood. The result is a decrease or elimination of zipper-type artifacts.

The examples of famous adaptive algorithms are listed below,

(a) Edge Sensing Interpolation (Hibbard & Robert 1995).
(b) Demosaicing by Successive Approximation (Li 2005).
(c) Pattern Recognition Interpolation (Cok & David 1986).
(d) Pattern Matching Interpolation (Wu et al. 1997).
(e) Alternate Projection Interpolation (Gunturk et al. 2002).

(g) Color Interpolation in effectively (Pei & Tam 2003).

(h) Variance of Color Differences demosaicing (King-Hong & Yuk-Hee 2006).

(i) Iterative Demosaicing (Chung-Yen 2006) are examples of adaptive algorithm.

1.1.6 Demosaicing Artifact

In demosaicing process some of the algorithms only can able to reconstruct the original image. After the demosaicing process the artifact affect the image in the redundant pattern. The some of the artifact listed as follows,

- Zipper effect: It is the one of common pattern in the demosaicing image enhancement domain, the Zipper Effect seems to be low-high-low pattern and vice versa. Normally this effect present in immediate edge of image with sharp transition in color levels. However, it generally occurs in the non adaptive demosaicing algorithm, because it does not have knowledge about the image pattern and wrong interpolation of two different color levels.

- False color: It is also a well known demosaicing artifact. The resulted output image is characterized by presence of aberrant colors. This phenomenon is frequently visible in the immediate transition of color components of the neighbor. This neighbour may miss interpolate pixel and less correlation with
reconstructed colors of a pixel. Because of this false color there is frequency gap between two colors David Alleysson et al. (2005). Generality it appears in the textured zone and it leads to difficulty in recognition of characters.

- Water color: This artifact is just opposite to the False color, it is due to underestimation of the chromatic band frequency. This artifact results dull color in demosaiced image.

- Grid effect: It resulted by low pass filter bandwidth over estimation. This leads to cross talking effect in color (chromatic) and achromatic channel.

- Blurring: In some demosaicing algorithms it uses low pass filters which is having a tendency to smooth or remove the high spatial pixel frequencies. So that the image loses its sharpness which tends to image blurring.

This introductory chapter emphasizes the significance of CFA sampling and demosaicing process done in single sensor digital cameras, problem statement, motivation and objective of CFA design and organization of the thesis.

### 1.2 Problem Statement

The problem in camera is its difficulties in differentiating colors when capture the scene, since the sensor records only light intensity, we can’t differentiate between colors. Thus, imaging sensors only record in black and white. The solution is color filtering, the most common form being the Bayer filter. The different forms of sampling patterns are available such as RGB, CMY, panchromatic RGBW or CMYW etc. with help of these color filters
raw data, demosaicing can be done which is nothing but the process of interpolation of missing color patterns. Because of CFA sampling, only 33.333% of color information can be got from the original scene. Successively, the interpolation technique is used to find out missing colors, the several artifacts which occur at the time of demosaicing. The most common artifacts are False coloring and zippering. So the proper selection of CFA and designing of demosaicing algorithm is mandatory.

1.3 MOTIVATION

Recently, innovation in color imaging technology has reduced complexity, size, and cost of imaging devices, such as digital cameras, display monitors, and printing devices, allowing more handy access to them in different environments. The very fast booming technology field in color imaging is digital photography which has gained significant popularity in recent years (Kiku et al. 2013). To realize formation of an image of a scene, digital cameras use a sensor, an array of light-sensitive spots, called photosites, which records the total intensity of the light that touches its surface. Commonly used image sensors have monochromatic characteristics which cannot record color information. Among existing solutions, a single-sensor imaging technology, which acquire visual imaging scenes in color using a monochrome (single color) sensor in conjunction with a color filter array (CFA), offers tradeoffs among cost, performance, and complexity (Manu Parmar & Stanley J Reeves 2004). Thus, the single-sensor solution is widely adapted to typical consumer grades digital cameras. Due to the advancement and proliferation of emerging digital camera based applications and commercial devices, such as digital mobile phones, IP camera, sensor networks, tablets, webcams, and personal digital assistants (PDA), the requirement for single-sensor imaging and digital camera image processing solutions will grow up considerably in the next decade.
In the first stage of pipeline, single-sensor cameras produce a mosaic-like image formed by intermixing samples from RGB channels, also called a raw CFA image (Chiu et al. 2014). The CFA image differs from a full color RGB image, as it contains only one color component at each pixel. In order to convert the CFA image to a full color RGB image, two missing components of each pixel are estimated by demosaicing operation. Then various image processing techniques are applied to the full color demosaiced image to enhance image quality.

The secret of the color filter array is that it prevents moire and false colors (Laurent Condat 2009). A sensor receives light, uses the three RGB filters for color separation, and performs interpolation based on the correlation of adjacent pixel information to create a color image. In the Bayer array each row or column features only 2 of the 3 R, G or B filter pixels. In developing the new color filter array, it ensures that all rows and columns are laid out with R, G or B filter pixels resulting in more realistic and accurate color representation and removal of ‘false color’. Incidentally, G(green) pixels is largest in number in this color filter array. Designer focused on G (green) pixels because green has the highest sensitivity (i.e., the most easily recognized by human eyes) in the visible spectrum. The new color filter array also has a balanced mixture of R (red) and B (blue) to enable natural color reproduction close to what human eyes see.

1.4 OBJECTIVE

- To propose a new Edge Preserve Non Threshold Interpolation algorithm to interpolate the CFA raw image.

- To propose Hybrid Edge-adaptive median filtering to remove demosaicing Artifacts.
To evaluate the improved performance of the proposed method, using PSNR (dB), s-CIELAB measures and Computational time Complexity.

1.5 SCOPE OF STUDY

The scope of the present research work is to design CFA pattern with optimal spectral sensitivity function and explore Edge Preserve Non Threshold Interpolation algorithm and Hybrid Edge-adaptive median filtering algorithm in which smoothen the edge region and obtain full color Demosaiced image. The methods are evaluated for the reconstruction of good visual perception images.

1.6 CONTRIBUTION

This research effort is focused on reducing the color difference between original image and reconstructed image generated from a single sensor camera device.

The accuracy of color acquisition device is increased by increasing the sampling of distinct colors. The periodic CFA color pattern is less prone to the optical and electrical cross talk demosaicing. In CFA Design Optimization with Image Formation Model, with the help of color filter sensitivity function to produce the mosaiced test image sample (i.e. raw CFA image) with optimum parameters such as focal length, optics characteristics and proposed RGBYC CFA array pattern.

In the Demosaicing of CFA raw data, the proposed demosaicing algorithm first interpolates the green samples with edge preserve non threshold algorithm. Then the remaining Red and blue color samples are interpolated. They are based on an assumption that the difference between the
red/blue pixel and the green pixel is a low pass signal. Then to point out the edge regions in an image, we apply Hybrid Edge-adaptive median demosaicing Artifact filtering. It will smoothen the edge region and obtain the Full color demosaiced image.

To analyze the result the performance evaluation is performed by measuring PSNR and s-CIELab values. The proposed method outperform better than the existing algorithm and high PSNR values, s-CIELab and computational complexity measurement is achieved.

1.7 ORGANIZATION OF THE THESIS

The organization of the thesis is outlined below.

Chapter 1 describes the overview, need for the CFA sampling, demosaicing motivation, objective of CFA design and organization of the thesis.

In chapter 2, survey of literature optimal CFA design and well known demosaicing algorithms along with performance analysis has been presented.

Chapter 3 explains the proposed method of spatial chromatic sampling framework processing steps such as optimal sampling pattern design RGB and RGBYC, Edge preserve non threshold demosaicing algorithm with interpolation of green, red, blue and other color channel from the proposed CFA pattern and results.

Chapter 4 explains Hybrid Edge-adaptive median demosaicing Artifact filtering algorithm used to filter the noise component that arises at the time of demosaicing and visual performance results.
Chapter 5 presents the performance evaluation of the proposed method with existing methods for Kodak and McMaster Data set.

Chapter 6 is the conclusion of the thesis which discusses some limitations and practical issues to be considered in future researches.