

Enhancement Techniques for True Color Images in Spatial Domain

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Abstract

The goal of Digital Image Processing is to process a digital image by means of a computer. Nowadays image processing is an exciting interdisciplinary field as it has wide range of applications in various fields like remote sensing, biomedical, industrial automation, office automation, criminology, military, astronomy, and space. Visual quality of an image may decrease during its sensing, storing, or sending. Image Enhancement basically improves the visual quality of an image by providing clear images. Based on color, images can be classified as gray scale and true color images. True color images represent full range of available colors that are similar to actual object. However a color images occupy more space when compared to gray scale images, they are very much useful for many applications. We reviewed in our previous paper about enhancement techniques for gray scale images in Spatial Domain. This paper extends those enhancement techniques to color images in spatial domain and results obtained gives better approach for its future research.

Keywords

Digital Image Processing (DIP), Color Image Processing (CIP), Histogram, Image Enhancement, Red Green Blue (RGB), Peak Signal to Noise Ratio (PSNR).

I. Introduction

Human beings use all the five sensory organs to gather information about the outside world. Among these five perceptions visual information and hearing information are important when compared to the other kinds of sensory information obtained from taste, smell, and touch. It is known that most of the information received by a human is visual from the images encountered from surroundings.

Digital image shown in fig. 1, is a 2D discrete light intensity function in which each element is referred as pixel. Let $f(x,y)$ be an original image where f is value of the pixel at spatial coordinates (x,y) .

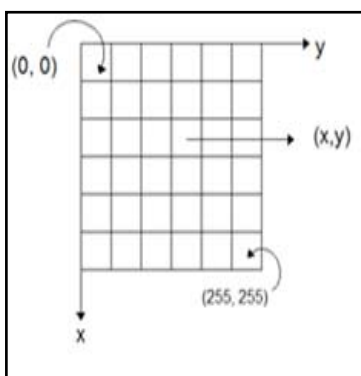


Fig. 1: An 8 bit Digital Image

Enhancement Techniques for Gray Scale Images in Spatial Domain have been reviewed [1] and implemented using MATLAB. Humans can distinguish many more colors than gray levels as color

is the perceptual sensation of light in the visible range incident upon the retina. An understanding of the perceptual processing capabilities of humans provided motivation for developing CIP algorithms. Every pixel of color image has both color and intensity. For visually acceptable results, it is necessary and almost sufficient to provide three color channels for each pixel. Color images can be represented by a stack of three matrices. A true color images use 24 bits to represent all colors, so that number of possible colors is 256^3 (or) 16777216.

II. Color Models

A color model is defined as standard way to specify a particular color by defining a 3D coordinate system, and a subspace that contains all constructible colors within a particular model [2]. Most common color models are: RGB, CMY, HIS, and YIQ where each model is oriented towards a specific application in CIP.

A. RGB Color Model

RGB is an additive color model in which three primary colors Red(R), Green(G), and Blue(B) form axis of a color cube shown in fig. 2. Each point in this RGB color cube represents a specific color.

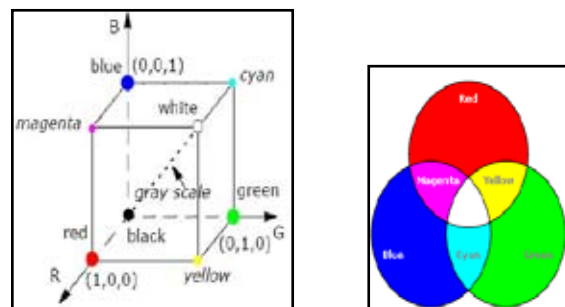


Fig. 2: RGB Color Cube and RGB Color Model

This model is good for setting electron gun for a CRT. Three secondary colors in this model are Cyan(C), Magenta (M), and Yellow (Y).

$$\left. \begin{aligned} C &= B + G \\ M &= B + R \\ Y &= R + G \end{aligned} \right\} \quad (1)$$

B. CMY Color Model

CMY is a subtractive color model in which three secondary colors Cyan(C), Magenta (M), and Yellow (Y) form axis of a color cube shown in fig. 3. Each point in this CMY color cube represents a specific color.

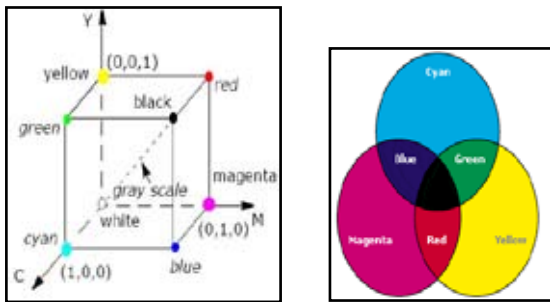


Fig. 3: CMY Color Cube and CMY Color Model

This model is used for producing images in printers. Three primary colors in this model are Red(R), Green (G), and Blue (B).

$$\left. \begin{aligned} R &= 1 - C \\ G &= 1 - M \\ B &= 1 - Y \end{aligned} \right\} \quad (2)$$

C. HSI Color Model

HSI stands for Hue, Saturation, and Intensity. H represents dominant color as perceived by a human observer. S refers to the relative purity or the amount of light mixed with hue. I reflects brightness. As HSI model is based on human color perception, it is very much useful for developing CIP algorithms.

Another similar model is HSV color model where HSV stands for Hue, Saturation, and Value of luminance. It can also be called as HSB where B is the brightness.

D. YIQ Color Model

In this model Y represents luminance where as I and Q describe the chrominance. This model is defined by the National Television System Committee (NTSC).

YCbCr color coordinate system, which was developed during world wide digital video component standard, is scaled and offset version of the YIQ.

Color images shown in fig. 4, can be represented by any of the four color models.

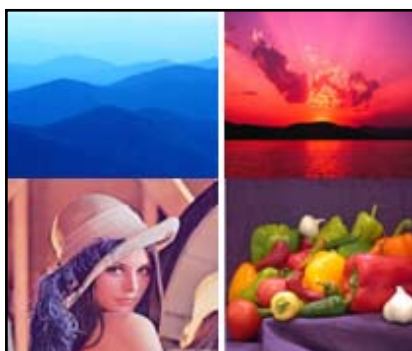


Fig. 4: Blue hills, Sunset, Lena and Pepper Images

Image enhancement methods are all very much problem oriented: a method suited for one problem may not be completely suited for another problem. Some of the common Enhancement Techniques for True Color Images in Spatial Domains are:

1. Point processing operations
2. Spatial filter operations
3. Histogram processing operations
4. Color to gray scale conversions

III. Point Processing Operations

This is the simplest spatial domain operation as operations are performed on single pixel only. Pixel values of the processed image $g(x,y)$ i.e. 's' depends on pixel values of original image $f(x,y)$ i.e. 'r' at (x,y) only as $s=T[r]$ i.e.

$$g(x,y) = T[f(x,y)] \quad (3)$$

where T is gray level transformation in point processing operation.

A. Color Components Extraction

This process extracts the required primary color components Red(R), Green (G), Blue (B) and also secondary color components Cyan(C), Magenta (M), Yellow (Y) from a digital color image. This is shown in fig. 5, for a Pepper image and is useful for developing CIP algorithms.

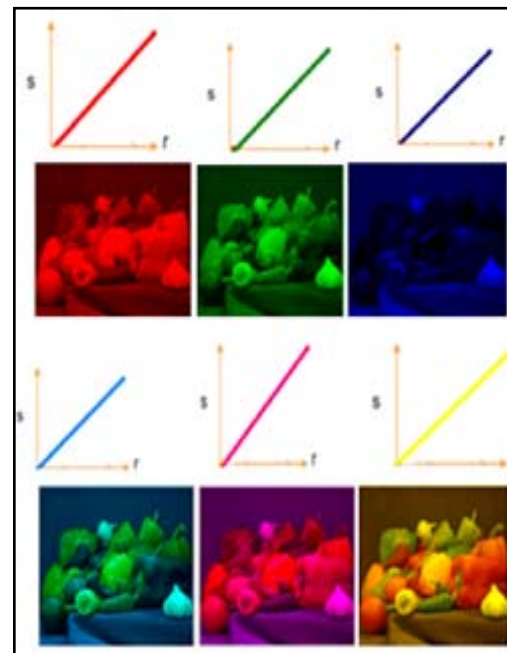


Fig. 5: Extraction of RGB and CMY Components

B. Image Negative Transformation

Negative image of a color image can be obtained by finding the complements of color [3]. Consider a 8 bit color image of size $M \times N$, then each pixel value from original image $f(x,y)$ is subtracted from 255 to get its negative image $g(x,y)$ as

$$g(x,y) = 255 - f(x,y) \quad \begin{cases} 0 \leq x < M \\ 0 \leq y < N \end{cases} \quad (4)$$

$$\text{In a normalized scale, } s = 1.0 - r \quad (5)$$

Negative images are useful for highlighting components embedded in the dark regions of a color image.



Fig. 6: Negative image of Pepper and Lena

C. Image Thresholding Transformation

Let r_{th} be a threshold value in $f(x,y)$. Image thresholding can be achieved as

$$g(x, y) = \begin{cases} 0 & f(x, y) \leq \text{threshold} \\ 1 & f(x, y) > \text{threshold} \end{cases} \quad (6)$$

In normalized scale

$$s = \begin{cases} 0 & r \leq r^{\text{th}} \\ 1 & r > r^{\text{th}} \end{cases} \quad (7)$$

This transformation is useful in image segmentation to isolate Region of Interest (ROI). Fig. 7, shows transformation for image thresholding along with result for Pepper image in which three channels have been binarized so that it has 8 distinct colors. Thresholded images are efficient in terms of their storage [4].

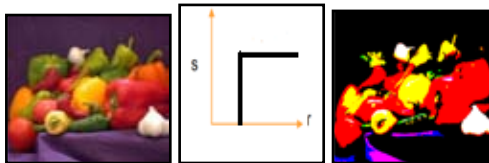


Fig. 7: Threshold image of Pepper

D. Contrast Stretching Transformation

This process improves the contrast by stretching the range of pixel values to span a desired range of pixel values [5]. This transformation is also called as image intensity transformation or normalization. Let a, b be the minimum and maximum pixel values of $f(x, y)$, and c, d be the minimum and maximum pixel values of $g(x, y)$. Normalization can be achieved by scaling each pixel in original image value as

$$s = (r - c) \left(\frac{b-a}{d-c} \right) + a \quad (8)$$

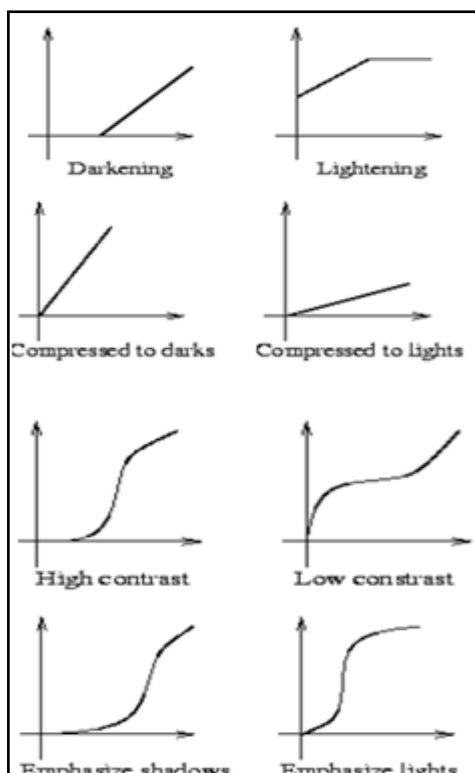


Fig. 8: Contrast Stretching Transformations

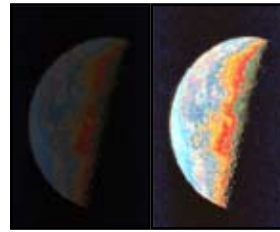


Fig. 9: Darken and Lighten Images of Moon

E. Log and Antilog Transformations

Logarithmic or log transformation maps a narrow range of pixel values into a wider range of pixel values (i.e. expand values of bright pixels and compress values of dark pixels). Inverse or anti logarithmic transformations performs opposite action. Log and Antilog transformations are:

$$s = c \log_{10}(1 + |r|) \quad (9)$$

$$s = 10^{\frac{|r|}{c}} - 1 \quad (10)$$

where, c is a scaling factor. Figures fig. 10 and fig. 11, indicate that log and inverse log operations are particularly used when gray level values of an image have extremely large range and small range respectively [6].



Fig. 10: Flower Image and its log Image

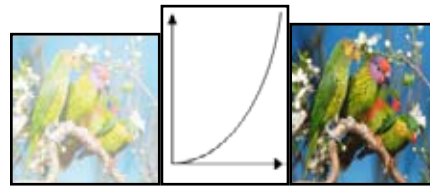


Fig. 11: Parrots Image and its Antilog Image

F. Power Law Transformation

The relation between pixel values of $f(x, y)$ and $g(x, y)$ in this transformation is

$$s = c r^{\gamma} \quad (11)$$

where, c and γ are positive constants.

If $\gamma < 1$ power law transformation maps a narrow range of dark pixel values into a wider range and wider ranges of bright pixel values to a narrow range. Opposite effect occurs for $\gamma > 1$. Identity transformation occur if $c = \gamma = 1$. Nowadays gamma correction is one of the quality assessment factor for a monitor where it has to correct all the images displayed on it [7].



Fig. 12: Three Different Gamma Corrected Images for $\gamma = 1$ (original), $\gamma = 4.0$ (brighten), and $\gamma = .25$ (darken).

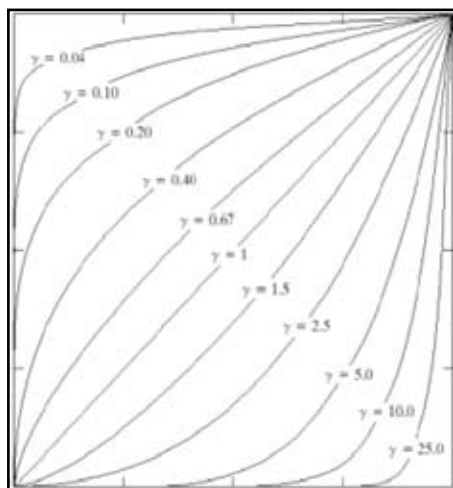


Fig. 13: Power Law Transformations

G. Piecewise Linear Transformation

This is an arbitrary user defined transformation. The amount of contrast stretching for three channels depends up on the choice of their (r_1, r_2) and (s_1, s_2)

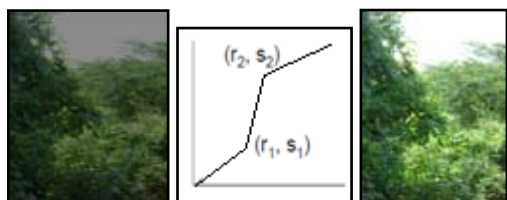


Fig. 14: Original Image and its Stretched Image

H. Color Slicing Transformation

This process highlights certain range of pixel values in three channels of a digital color image. This is equivalent to spatial band pass filtering as shown in fig. 15, where it emphasizes pixel values between A and B with and without preserving rest.

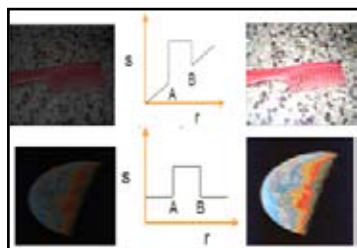


Fig. 15: Comb, Moon Images Along With Their Sliced Images With and Without Back Ground

I. Flipping and Rotating Operations

Flipping operation flips an image from left to right (i.e. columns flipped left-right directions about a vertical axis) and/or from top to bottom (i.e. rows flipped in the up-down direction about horizontal axis). Rotating operation rotates an image around its centre point by an angle $\pm\theta$ degrees where, + and - signs indicate counter clockwise and clockwise directions. During these flipping and rotating operations, pixel values of an image do not change, but change is in their positions as shown in fig. 16 and fig. 17.



Fig. 16: Myna Image and Its Flipped Images

Fig. 17: Lotus and its Rotated (± 30 Degrees) Images

J. Bit Plane Slicing

This process highlights contribution made to total image appearance by specific bits used for pixel levels of three channels. Eight 1 bit planes can be formed for an 8 bit image for each channel. Fig. 18, shows that plane 7 contains majority of the visually significant data and planes 6, 5, and 4 contributes more suitable details and rest of the planes 3, 2, and 0 are all full black contributes nothing. Bit plane slicing represents the adequacy of number of bits used to quantize each pixel for three channels in image compression

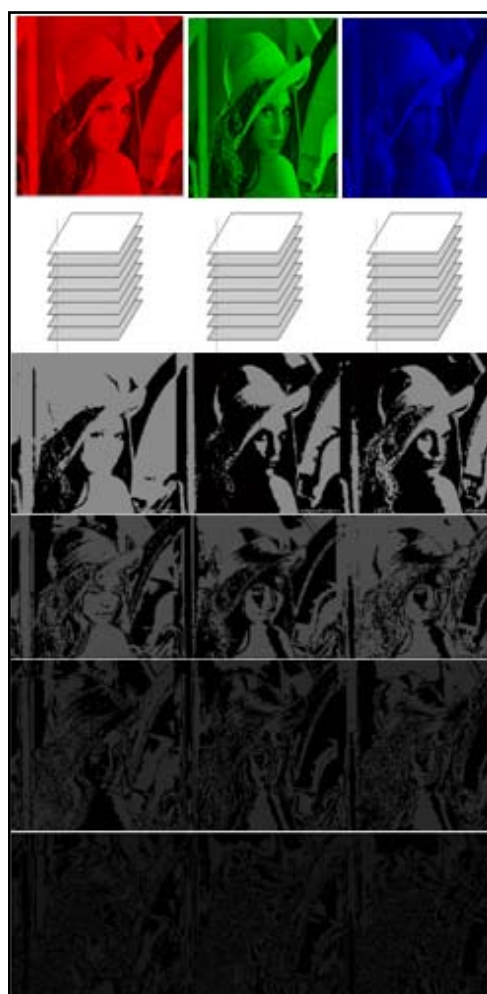


Fig. 18: Bit Plane Slicing of Lena Image for Each of Three Channels and Their Bit Plane Images (7, 6, 5, 4).

IV. Spatial Filter Operations

As spatial filtering operations are performed on a pixel along with its immediate neighbors, this is also called as neighborhood processing operations. Spatial filters are classified as: Linear and Nonlinear

A. Linear Spatial Filter

This process involves convolving a mask with an image i.e. passing a weighted mask over the entire image. Mask is also referred as window, template, or kernel. A 3x3 mask and sub image of original image under this mask at (x,y) is shown in fig. 19.

$\omega(-1,1)$	$\omega(0,1)$	$\omega(1,1)$	$f(x-1,y+1)$	$f(x,y+1)$	$f(x+1,y+1)$
$\omega(-1,0)$	$\omega(0,0)$	$\omega(1,0)$	$f(x-1,y)$	$f(x,y)$	$f(x+1,y)$
$\omega(-1,-1)$	$\omega(0,-1)$	$\omega(1,-1)$	$f(x-1,y-1)$	$f(x,y-1)$	$f(x+1,y-1)$

Fig. 19: A 3x3 Mask and Sub Image Under This Mask

Three steps in linear spatial filtering are:

1. Extract Y components from color image using RGB to YIQ conversion
 2. Perform linear filtering operation on Y components in spatial domain.
 3. Get filtered color image by using YIQ to RGB conversion.
- Linear spatial filtering is achieved by linear convolution of sub image with mask:

$$g(x,y) = f(x,y) * \omega(x,y) \quad (12)$$

$$= \sum_{a=-1}^{+1} \sum_{b=-1}^{+1} f(x+a,y+b) \omega(a,b)$$

1. Low Pass Filter (LPF)

This process replaces every pixel in the original image by average of all the pixels in its local neighbors. This is also called as averaging, mean, or smoothing. LPF preserves smooth regions in the image and removes sharp variations that lead to blurring effect. This filter reduces noise.



Fig. 20: Lena Image and its 3x3 LPF Image

In weighted average filter pixels nearer to the centre are more weighted than the distant pixels. A Gaussian filter is used for removing noise drawn from a normal distribution. A Bartlett filter mask can be obtained by convolving two LPF masks.

			1	2	3	2	1			
		1	3	3	1					
1	2	1	3	9	9	3	3	6	9	6
2	4	2	3	9	9	3	2	4	6	4
1	2	1	1	3	3	1	1	2	3	2

Fig. 21: Weighted Mean, Gaussian and Bartlett Masks

2. High Pass Filter (HPF)

A HPF enhances sharp details. This process is also called sharpening an image. A High Boost Filter (HBF) also emphasizes high frequency components, but at the same time retains some of the low frequency components as shown in fig. 22.

$$g(x,y)_{HBF} = (A-1) f(x,y) + g(x,y)_{LPF} \quad (13)$$

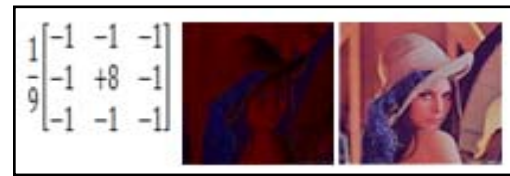


Fig. 22: Lena's 3x3 HPF and HBF Images with A=1.5

Modification of a High Pass Filter gives different operators for detecting points, edges (right and bottom) and lines (horizontal, vertical, and $\pm 45^\circ$) in an image. A Laplacian filter detects edges of an image even in the presence of high level of noise.

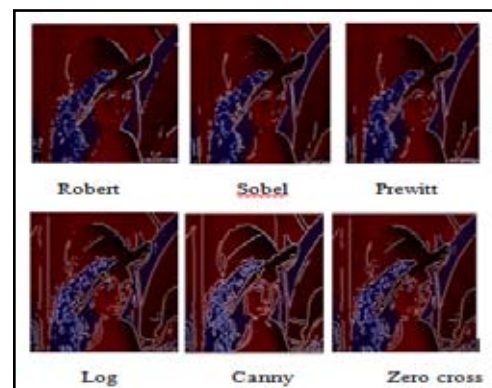


Fig. 23: Six Edge Detected Images of Lena Image

B. Non Linear Spatial Filter

In this filter enhanced image $g(x,y)$ at (x,y) is non linearly related to the pixels in neighborhood of original image $f(x,y)$ [8]. Three steps in nonlinear spatial filtering are:

1. Extract R, G, and B components from image using RGB color model
2. Perform nonlinear filtering operation on R, G, and B components.
3. Get non linear filtered color image by using RGB color model.

Maximum filter is used to locate the brightest point in an image. It is a 100th percentile filter used to remove salt noise.

$$g(x,y) = \max[f(x+a,y+b)] \quad \begin{cases} -1 \leq a \leq +1 \\ -1 \leq b \leq +1 \end{cases} \quad (14)$$

Minimum filter is used to locate the darkest point in an image. It is a zeroth percentile filter used generally to remove pepper noise.

$$g(x,y) = \min[f(x+a,y+b)] \quad \begin{cases} -1 \leq a \leq +1 \\ -1 \leq b \leq +1 \end{cases} \quad (15)$$

Median filter is a statistical filter used to locate the median value of the pixels. It removes both salt and pepper noise. This filter provides less blur but rounds corners.

$$g(x,y) = \text{med}[f(x+a,y+b)] \quad \begin{cases} -1 \leq a \leq +1 \\ -1 \leq b \leq +1 \end{cases} \quad (16)$$



Fig. 24: Moon Image, Its Noisy Image With Salt and Pepper Noise and Its Median Filtered Images

V. Histogram Processing Operations

Histogram of a color image gives number of times a particular color has occurred in the image so that it shows color balance of an image.

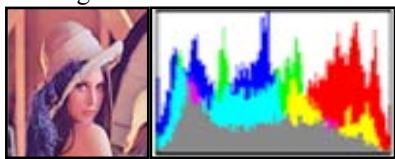


Fig. 25: Histogram of Lena Image

To find histogram of a color image extract R, G, and B components from color image using RGB model and then find histograms separately for R, G, and B channels as shown in fig. 26.

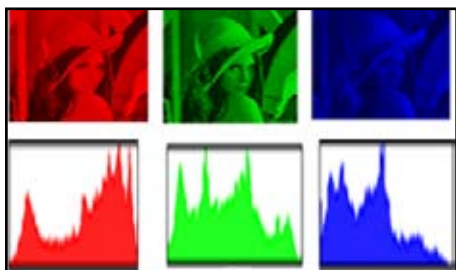


Fig. 26: Histograms of R, G, and B Components of Lena Image Using RGB Model

Even though histogram contains no spatial information, many CIP algorithms can be developed based on histograms.

A. Histogram Equalization

This technique enhances appearance of an image by spreading pixel levels so that they are evenly distributed across their range

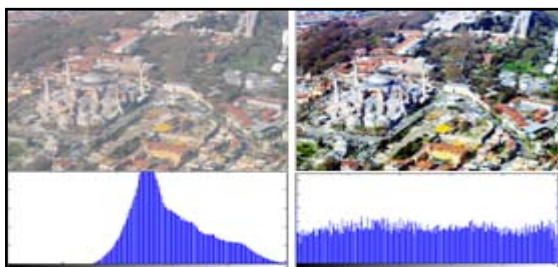


Fig. 27: Aerial Image and its THE Image

Three steps in Traditional Histogram Equalization (THE) of a color image are:

1. Extract Y components from color image using RGB to YIQ conversion
2. Perform histogram equalization for Y components only.
3. Get equalized color image by using YIQ to RGB conversion.

THE is quite useful but not suitable for interactive image processing applications as it gives only one resultant image [9].

B. Histogram Specification

Histogram specification or matching automatically determines a transformation function required to produce an output image with a uniform histogram.

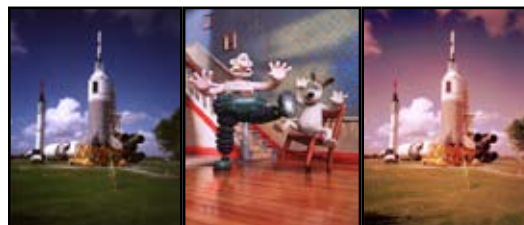


Fig. 28: Histogram Matching of Rocket image with Mickey Mouse Image

C. Local Enhancement

This method involves moving the centre of a square mask from pixel to pixel over entire image. For each neighborhood calculate histogram and map the centre pixel with the histogram equalization or specification. This method of enhancing images using local histogram is also known as Adaptive Histogram Equalization (AHE).



Fig. 29: Tomato Image and its THE and AHE Images

This method give details over small areas in an image, but sometimes fails to enhance dark and bright images. Histograms statistics can also be used to map the centre pixel with moments.

VI. True Color to Gray Scale Conversions

Human beings can distinguish many more colors than gray levels. But for some applications grayscale images are more useful as they need less memory space for storage and lower computational complexity during their processing when compared to true color images.



Fig. 30. True Color and Their Gray Scale Images

VII. Conclusions

Image enhancement techniques for gray scale images in spatial domain have been extended and implemented to true color images successfully using MATLAB and also discussed results for each method. This paper considers true color images from different fields. Based on the type of image and type of noise with which it is corrupted, a slight change in individual method or combination of methods further improves visual quality. Computational cost of each algorithm, Correlation coefficient, or PSNR plays a critical role while selecting an algorithm for real time applications. The future scope will be the development of parameterized model with which effective image enhancement can be achieved using adaptive algorithms.

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of interest includes 1D & 2D signal processing.



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