An Approach to Color Image enhancement Using Modified Histogram

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***ABSTRACT*---Image enhancement is one of the key issues in high quality pictures such as digital camera and HDTV. Since Image clarity is very easily affected by lighting, weather, or equipment that has been used to capture the image. These conditions lead to image may suffer from loss of information. In this paper a new technique is introduced to enhance color images with dim regions ,In this technique the lightness component in YIQ color space is transformed then the traditional histogram equalization (HE) method is applied on Y component. The result of modified histogram equalization (MHE) algorithm has been compared with the result of other method like Adaptive Integrated Neighborhood Dependent Approach for Nonlinear Enhancement of Color Images (AINDANE), traditional histogram equalization and Homomorphic Filtering. All algorithms have implemented using Matlab.**

***Keywords - H*istogram equalization, Homomorphic Filtering, color space, nonlinear enhancement**.

I. INTRODUCTION

Color images provide more and richer information for visual perception than that of the gray images. Color image enhancement plays an important role in Digital Image Processing [1]. The purpose of image enhancement is to get finer details of an image and highlight the useful information. During poor illumination conditions, the images appear darker or with low contrast. Such low contrast images needs to be enhanced.

Numerous methods are available in the literature for image enhancement [3]–[9]. The enhancement methods can broadly be divided in to the following two categories:

1. Spatial Domain Methods 2. Frequency Domain Methods

In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. Image enhancement is applied in every field where images are ought to be understood and analyzed. For example, medical image analysis, analysis of images from satellites etc.

This paper is organized as follows: Section II presents the algorithms used for color enhancement. Section III reports some experimental results and provides corresponding analyses. Thereafter, Section IV concludes.

II. ALGORITHMS USED FOR COLOR ENHANCEMENT

A.Histogram Equalization

The histogram of digital image with grey levels in the range [0,L-1]is a discrete function $p(r_k)=n_k/n$, where r_k Is the k^{th} grey level, n_k is the number of pixels in the image and k=0,1,2,……..L-1. $p(r_k)$ gives an estimate of the probability of occurrence of grey level r_k. A plot of this function for all values of ‘k’ provides a global description of the appearance of an image, if the grey levels are concentrated towards the dark end of grey scale range the histogram corresponds to overall dark characteristics, if grey levels occurred int the middle of gray scale the image would appear murky, if the grey levels are in the right most then the resulting image is bright.

Histogram equalization (HE) is the technique used to obtain uniform histogram. The gray levels in an image are may be viewed as random quantities in the interval [0,1].If they are continuous variables the original and transformed grey levels are characterized by the probability density function $p_r(r)$ denotes the probability density function (PDF) of the lightness levels in a given image, for any gray level in the range, we focus attention on transformations of the form

$$s = T(r) = \int_0^r P_r(W)dw \qquad (1)$$

Where 'w' is a dummy variable of integration. The rightmost of equation (1) is recognized as cumulative distribution function of 'r' The probability density function of the output levels is uniform, such that [4]:

$$P_s(s) = \begin{cases} 1 & for\ 0 \le s \le 1 \\ 0 & otherwise \end{cases} \quad (2)$$

When dealing with discrete quantities, we will work with histograms, and call the preceding technique histogram equalization, such that

$$s_k = T(r_k) = \sum_{j=0}^{k} P_r(r_j) = \sum_{j=0}^{k} \frac{n_j}{n} \quad (3)$$

Where: j=0,1…..k, r_k is the normalized intensity level of the input image corresponding to the (non-normalized) intensity level k: (r_k =0..1) and (k =0..L) and L =255 for lightness band with 8 bit/pixel), s_k corresponds to normalized intensity level of the output image. The cumulative probability density function (CPDF) calculated by

$$P_c(r_k) = \sum_{j=0}^{k} P_r(r_j) = \sum_{j=0}^{k} \frac{n_j}{n} \quad (4)$$

r_j is normalized intensity level of the input image corresponding to the (non–normalized) intensity level j , and r_j given by

$$r_j = \frac{j}{L}, \text{ j=0,1,2……L} \quad (5)$$

Where n_j being the number of pixel with intensity j and n is the total number of pixels of the image.

B. AINDANE Algorithm

Adaptive Integrated Neighborhood Dependent Approach for Nonlinear Enhancement of Color Images (AINDANE) [6] is an algorithm to improve the visual quality of digital images captured under extremely low or uniform lightening conditions. it is composed of three main parts: adaptive Luminance enhancement, contrast enhancement and color restoration, this algorithm can be discussed as following:

1) Adaptive luminance enhancement: It consists of two steps, the first step is luminance estimation can be obtained by using National Television Standards Committee (NTSC) color space. Intensity values of RGB image can be obtained using the following [10]:

$$I(x,y) = 0.289r + 0.587g + 0.114b \quad (6)$$

Where r,g,b are the red, green, blue components for the color image in RGB space. And the normalized intensity is:

$$I_n(x,y) = I(x,y)/255 \quad (7)$$

The image information according to human vision behavior can be simplified and formulated as

$$I(x,y) = L(x,y)R(x,y) \quad (8)$$

Where R(x,y) is the reflectance and L(x,y) is the illumination at each position, the luminance L is assumed to be contained in the low frequency component of the image while the reflectance R, mainly represents the high frequency components of the image. For estimation of illumination, the result of Gaussian low-pass filter applied on the intensity image is used. In spatial domain, this process is a 2D discrete convolution with a Gaussian kernel which can be expressed as

$$I_c(x,y) = L(x,y) = I(x,y) * F(x,y,c) \quad (9)$$

The I_c is image convolution, symbol * denotes convolution. Gaussian surrounds function that is calculated by

$$F(x,y,c) = k\exp(-(x^2 - y^2)/c^2) \quad (10)$$

k is determined using the condition

$$\iint F(x,y,c)dxdy = 1 \quad (11)$$

The second step is called adaptive dynamic range compression of illuminance it can be obtained using the transfer function by

$$L_n = \frac{I_n^{0.24} + (1-I_n)0.5 + I_n^2}{2} \quad (12)$$

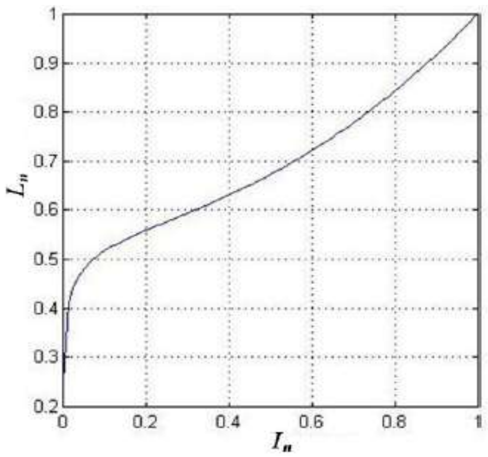

Fig.1 I_n versus output lightness L_n.

This transformation can largely increase the luminance for the dark pixels, Fig.(1) illustrate the relationship graphically.

2) Contrast enhancement: It is done by Center- surround contrast enhancement by using

$$R(x,y) = 255L_n(x,\ y)^{E(x,y)} \qquad (13)$$

$$E(x,y) = \left[\frac{I_c(x,y)}{I(x,y)}\right]^p \qquad (14)$$

Where 'p' is a constant can be manually adjusted by users to tune the contrast enhancement process generally its value is ($0 \leq 5p \leq 2$) it depends on the global standard deviation of the input intensity image. According to this method, if the center pixel's intensity is higher than the average intensity of surrounding pixels, the corresponding pixel on the intensity-enhanced image will be pulled up; otherwise it will be pulled down.

3) Color restoration: A linear color restoration process is applied; It is applied to convert the enhanced intensity image to RGB color image. The (r',g',b') of the restored color image are obtained by using

$$r' = h\frac{r}{I}r,\ g' = h\frac{R}{I}g, b' = h\frac{R}{I}b \qquad (15)$$

$$R(x,y) = \sum_i W_i\, R_i\,(x,y) \qquad (16)$$

Where i=1, 2, 3…represents different scales and w_i is the weight factor for each constant enhancement and were calculated from equation (13) . The scales used in this search are: *c1=5*, *c2= 20* and *c3=240* and *w1=w2=w3=1/3*.

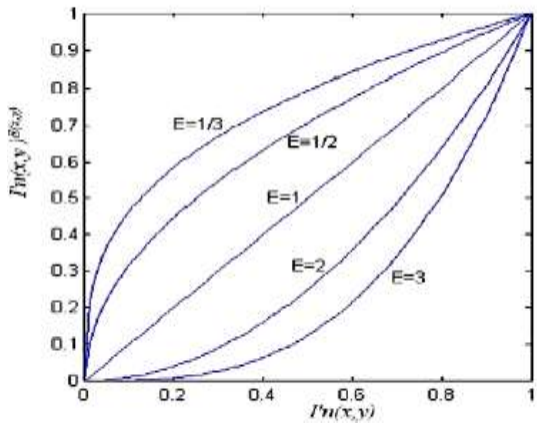

Fig.2 I'$_n$(x, y) and I'$_n$(x, y)^E(x, y)

C. *Modified Histogram Equalization Algorithm(MHE)*

This algorithm involves four steps:

1. Transform color image from basic RGB color space to YIQ color space using

$$\left.\begin{aligned} y &= I \\ i &= 0.596r - 0.27g = 0.322b \\ q &= 0.211r - 0.253g + 0.312b \end{aligned}\right\} \qquad (17)$$

   Where 'y' is lightness component, i, q are chromatic components

2. Transform normalized lightness value by using sigmoid function that is given by

$$s_n = 1/(1 + \sqrt{\frac{1-I_n}{I_n}}) \qquad (18)$$

3. Apply Histogram equalization on modified lightness component(y_n)
4. Apply inverse transform to get RGB color space from YIQ color space using

$$\left.\begin{aligned} r &= Y_p + 0.956i + 0.621q \\ g &= Y_p - 0.272i - 0.647q \\ b &= Y_p - 1.16i + 1.703q \end{aligned}\right\} \qquad (19)$$

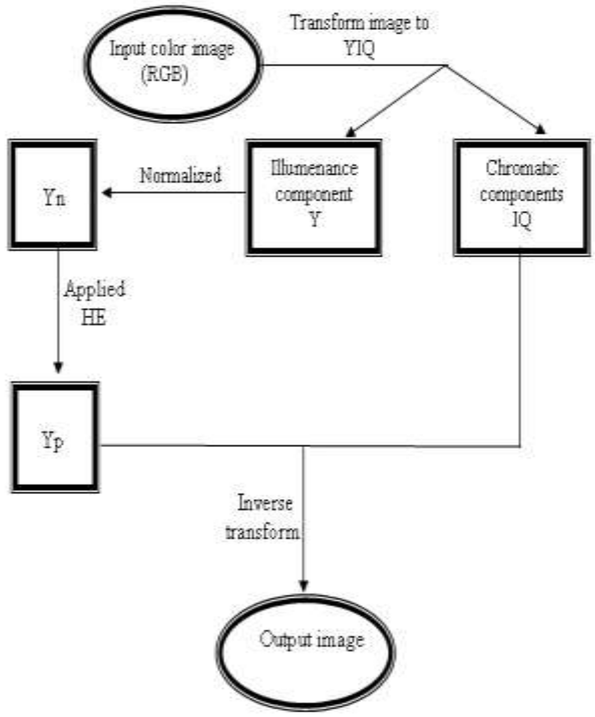

Fig.3 Stages of MHE algorithm

D. *Homomorphic Filtering*

Homomorphic filtering [2] is a frequency domain procedure that is useful for improving the appearance of an image by simultaneous brightness range compression and contrast enhancement. This algorithm involves the following steps

1. Transform color image from basic RGB color space to HSV color space using

$$H = \begin{cases} H_1, \text{ if } B \le G \\ 360 - H_1, \text{ if } B > G \end{cases} \quad (20)$$

Where

$$H_1 = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-G)]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\} \quad (21)$$

$$S = \frac{\max(R,G,B)-\min(R,G,B)}{\max(R,G,B)} \quad (22)$$

2. Apply forward Fourier transform to the logarithm of the 'V' component
3. Perform linear filtering
4. Apply inverse operation to get desired enhanced 'V' component
5. Transform color image from basic HSV color space to RGB color space

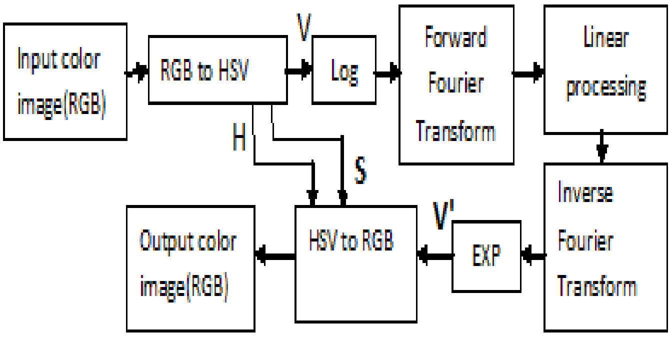

Fig.4 *Block Diagram of* Homomorphic Filtering

III. RESULTS

The proposed image enhancement algorithm has been applied to process digital images taken by digital still image cameras under various illuminating conditions. The output images generally have a good quality, with fine details, well-balanced contrast and luminance across the whole image. The proposed algorithm has been applied to large number of digital images captured under dark illumination conditions for performance evaluation and comparison with the other techniques. The algorithm is compared with other methods in subjective and objective point of view.

A. Subjective Evaluation:

Here we compared the performance of the proposed method with histogram equalization, AINDANE and Homomorphic filtering [2]. The enhanced image using proposed method has a good quality, with fine details, well-balanced contrast and luminance across the whole image. The original color of the image is changed after Enhancing using histogram equalization, Homomorphic filtering and the global enhancement using AINDANE is satisfactory but the local details are still to be enhanced and the color is also changed slightly due to the use of color restoration process in RGB space. Fig. 7 shows three input color images containing both dark and bright regions and result of the image enhancement by histogram equalization, AINDANE, Homomorphic filtering and proposed method.

B. Objective Evaluation:

In this method, the statistical properties [3] of image, mean, and the mean of zonal standard deviation, are used to access visual quality of the image in terms of image contrast and details. Therefore the image is divided into possible number of non overlapping 8 x 8 pixel blocks. For each block mean and standard deviation is calculated and plotted as shown in Fig. 5. About 70% of the blocks is inside the visually optimal region after Enhancement on proposed method. On the other hand only about 35% of the blocks are inside the visually optimal region after enhancement using Homomorphic filtering method. Table II shows mean and variance of different methods mean variance is improved in proposed method Table I shows the mean errors of Homomorphic filtering, histogram equalization, AINDANE and MHE. Mean error is less in MHE when compared to other methods; Fig.6 shows the histograms of different algorithms.

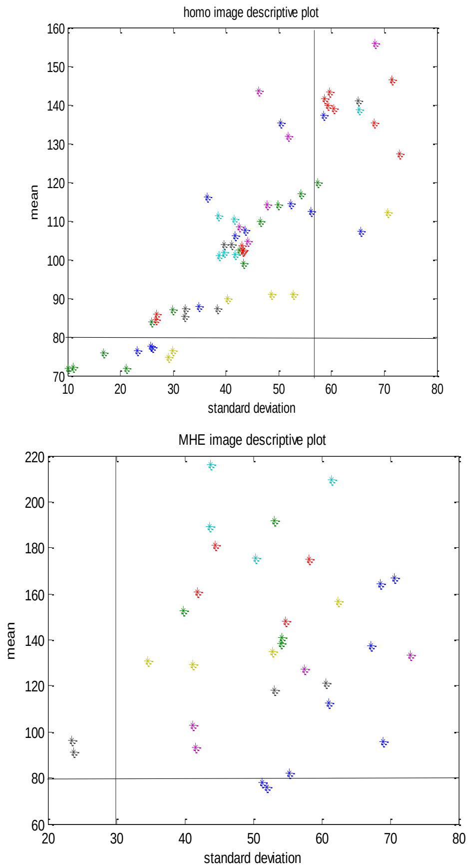

Fig 5. Statistical characteristics of image before and after enhancement (a) enhancement using Homomorphic filtering method (b) enhancement using proposed method.

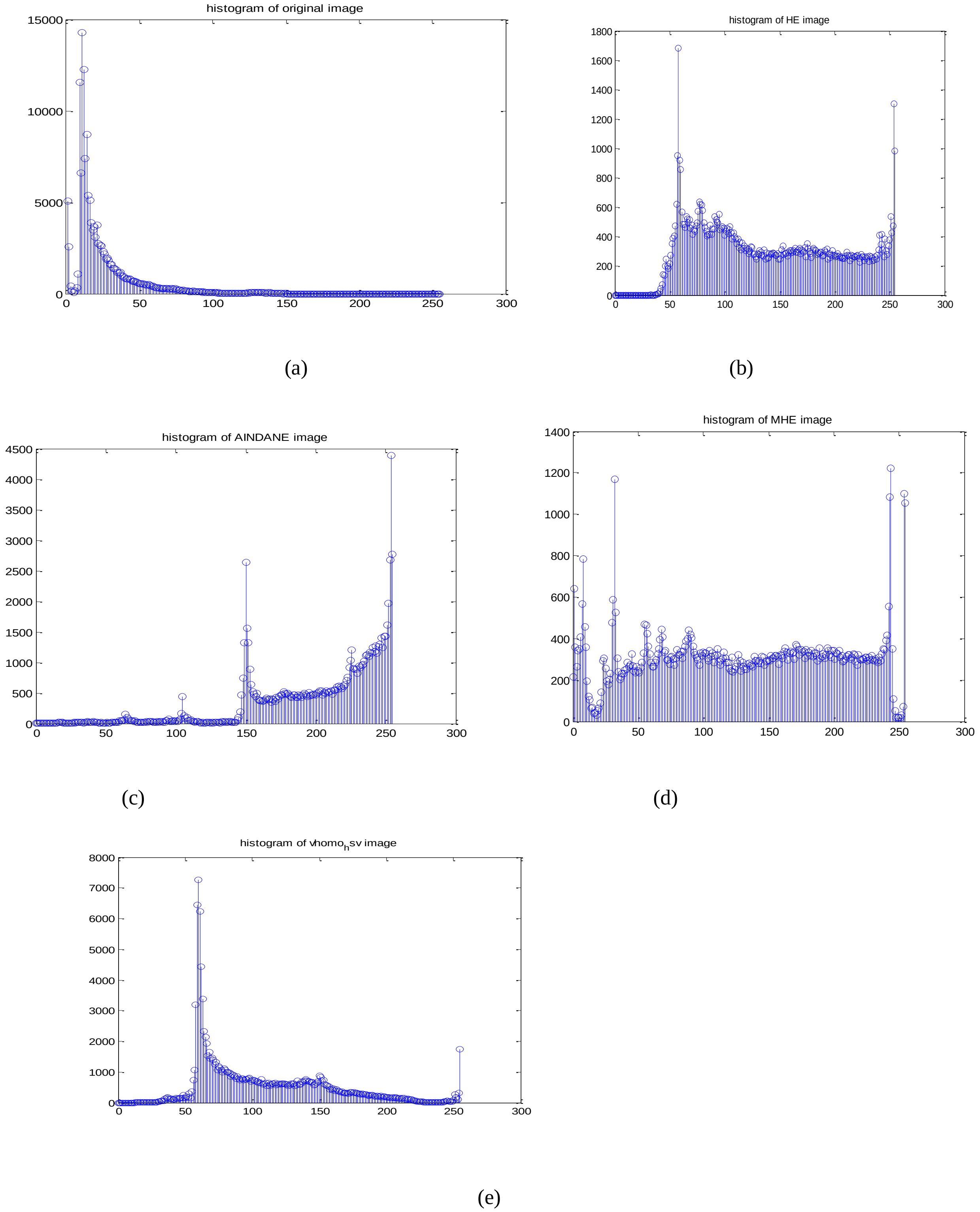

Fig.6 Comparison of Histogram with different methods: (a) original images (b) Histogram equalization, (c) AINDANE, (d) Modified Histogram equalization (e) Homomorphic filtering

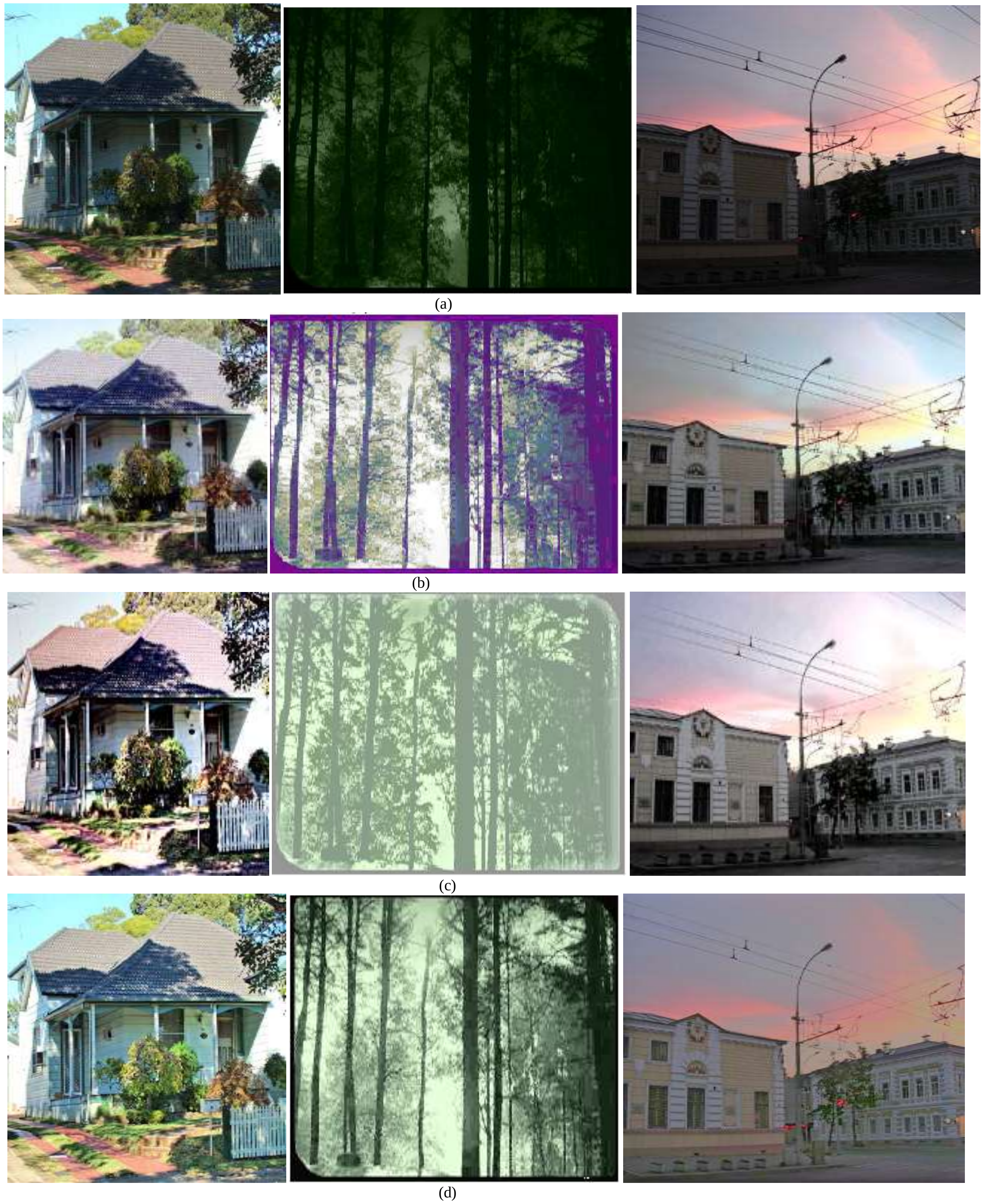

Fig 7. Image enhancement comparison with different methods: (a) original images and results of (b) enhanced images using histogram equalization, (c) Enhanced images using Homomorphic filtering, and (d) enhanced images using proposed method.

TABLE I

BLOCK MEAN ERROR OF DIFFERENT ALGORITHMS

HE	Homomorphic	AINDANE	MHE
3.419	3.52	4.9	2.415

TABLE II

MEAN AND VARIANCE FOR DIFFERENT ENHANCEMENT METHODS

Image	Original		Homomorphic		AINDANE		HE		MHE	
	VAR	MEAN	VAR	MEAN	VAR	MEAN	VAR	MEAN	VAR	MEAN
1.	4.754	1.084	4.1645	4.6046	3.437	6.0047	3.572	4.499	5.651	3.4459
2.	3.14	1.285	2.78	3.529	3.792	2.956	3.202	3.28	4.026	3.21
3.	3.26.	1.58	2.849	2.34	2.19	1.166	3.351	2.136	3.924	3.45

IV. CONCLUSION

A new image enhancement algorithm has been proposed to improve the visibility of digital images, Computational load of this method is less than other methods. So, this method is easily implemented with less hardware and less memory for real time processing. These properties ensure that the MHE is robust method to enhanced color image with deferent lightness levels.

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