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Brightness Preservation by Fuzzy Based Multi-Peak Generalized Histogram Equalization

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ABSTRACT

The range of brightness levels and Histogram shows how individual brightness levels are occupied in any image, for image contrast measurement .Low-level image processing is one of the most important issues of image enhancement. To control and enhance the contrast, Histogram Equalization (HE) is the simple and effective technique, but this approach causes some unnatural look in output image. For best effect the brightness of input image must be retained. Fuzzy techniques can manage the vagueness and ambiguity efficiently. Fuzzy logic is a powerful tool to represent and process human knowledge in form of fuzzy *if-then* rules. In this work we are using fuzzy membership function in the proposed algorithm. The proposed concept in this paper is named as *Brightness Preservation by Fuzzy based Multi-peak Generalized Histogram Equalization (BPFMGHE*) and it is simulated by MATLAB; this technique first combined the global histogram equalization of image with local information and then after calculating noise free generalised multi-peak histogram by equalization, the image was again decomposed into several sub-images, and then applied the fuzzy membership function dependent HE process to each of them to preserve image brightness.The distribution of grey level is in complete control with the given method and image improvement is effective. Image is improved and brightness is preserved effectively with the discussed process.

Introduction

Refining of image for better brightness is a challenging job in image processing. The grey level difference between object and background plays important role in improving the intensity. With the help of *local* and *global* methods the simulation is achieved.

a) **Local method** The use of Edge operator or local mean, standard deviation best describes local method. The contrast enhancement is seen as modified features, and impressive local texture enhancement. Image texture improvement serves the purpose of image contrast improvement. But due to non-monotonic mapping the image is distorted.

b) **Global method** Improvement is done with Histogram modification method. HE is applicable to low contrast image in condition that i) image is mono-objected ii) contrast change between background and image is not significant. Both condition cannot be fulfilled at the same time so the global method suffers from over and under enhancement defects.

The remedy for above drawbacks is discussed in (Y.Wang, et al 1999, H.C. Zhu et al 1999, K. Wongsritong et al 1998). Suppose the subsets obtained between [xi, xi+1] for grey level range [x_0, x_L], and the mid-nodes obtained (mean, median or spike) in the image histogram is x_i (i=1,2,……..,L-1). The original histogram is divided in subsets. Process is employed on each subsets and independently called as Multi-peak HE. Small improvement with defects of HE is observed.

The proposed Fuzzy based Multi-peak GHE method is very effective not only in enhancing the entire image but also in enhancing the textural details to improve the local contrast of the original Image, described in details in Section III. Image is improved effectively as the method controls the order of grey level of original image.

The paper is organised as Section II shows Conventional histogram. Section III shows proposed method BPFMGHE. Sections IV shows Simulation, qualitative and qualitative discussion and Section V Conclude the paper.

Previous Work

The demerits of BBBE, DSIHE, MMBEBHE, RMSHE is discussed in this section and noted . In BBHE(Y. Kim 1997)- a) Splitting histogram at mean value of input image. b) Equalize each section solely. BBHE retains the original brightness and brightness is preserved. In DSIHE (Wan et al 1999)- Histogram separation(median based). MMBEBHE (Chen and Ramli 2003), is the functional BBHE Mathematical formulation of method. The brightness error of input and output image is the optimal point splitting. Besides improvement some nuisance is also seen in grey level of histogram. RMSHE employs recursive algorithm to divide histogram into many sub-histogram (S. D. Chen and A. R. Ramli 2003). Sub sections of histogram is obtained recursively depending on the mean brightness separation. So calculated number of sub-histogram is obtained for equalization by HE independently. But the discussed methods fails to expand the histogram at its boundaries of dynamic range. The nuisance like washed-out appearance, checkerboard effects, low image brightness is seen.

DHE dealt the above defects which partitions the histogram based on local minima (Abdullah-Al-Wadud et al 2007) but do not preserve brightness. BPDHE is improvement to DHE technique (Ibrahim and Kong 2008) which assigns a new dynamic range to sub-histogram. Output intensity normalization to equalize the input and output intensity for local

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maxima based separation is processed. If the ratio for normalised brightness is low, the image shows non-noticeable contrast enhancement. Saturation problem is encountered when exceeded pixel (ratio more than 1) is quantized.

For the removal of saturation the BPDFHE method is employed for HE (Sheet et al 2010). The BPDFHE technique confines grey value in between two consecutive peaks (valley). It ensures that there is no remapping of peaks should occur. Result is the improved image with small defects.

Pioneer Classical HE Method (CHE)

In this method the range is expanded within whole domain and the equal distribution of grey level in entire domain is ensured. Means HE enhanced output image uses all the gray-level's image domain, i.e. 0 to L-1. Uniform distribution property encloses Maximum information of image (Y.Wang, et al 1999), i.e. entropy of a message source is maximum. Besides maximum information content CHE method fails to preserve brightness and a shift to L/2 is encountered. This shift to L/2 is not desirable.

Multi Peak GHE

Multi-peak GHE technique is just a modified method of multi-peak HE. Density function p(g(x, y)) is employed for simulation. Step by step operation performed by this technique is shown in Fig. 1.

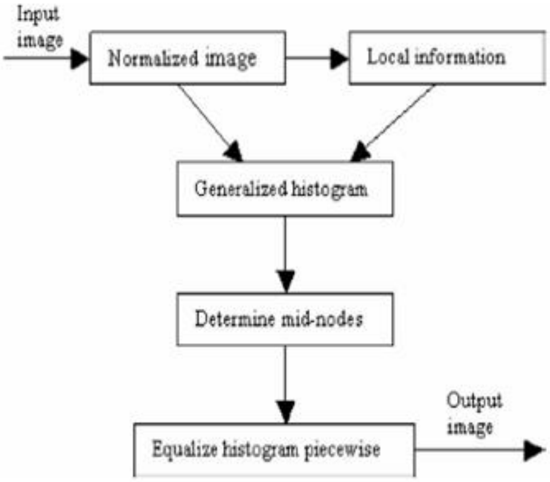

Figure 1. The Process flow in Multi peak GHE

Multi Histogram Equalization Method With Fuzzy Logic

GHE is characterized by re-mapping of histogram peaks which changes the brightness level to a large extent. But BPDFHE technique (Sheet et al 2010) prevents the re-mapping and distributing the grey level value in the consecutive peaks for better enhancement with brightness preservations. In this technique following operation validates the process.

A) Fuzzy Histogram generation.
B) Splitting the Histogram.
C) Apply DHE on each split.
D) Calculation of Normalize value for image brightness.

Brightness Preservation by Fuzzy Based Multi-Peak Generalized He

The proposed method is named as Brightness Preservation by Fuzzy based Multi-peak Generalized Histogram Equalization (BPFMGHE). In this method, previously explained BPDFHE will be improved by the concept of Multi–peak GHE. Steps of operation starts from combining global histogram equalization with local information then after calculating noise free generalised multi-peak histogram by constant distribution equalization; we again decompose the image into several sub-images, and then applying the classical fuzzy based Dynamic HE process to each one of them; which provide configuration options to consumers in BPDFHE by doing variation in alpha and beta.

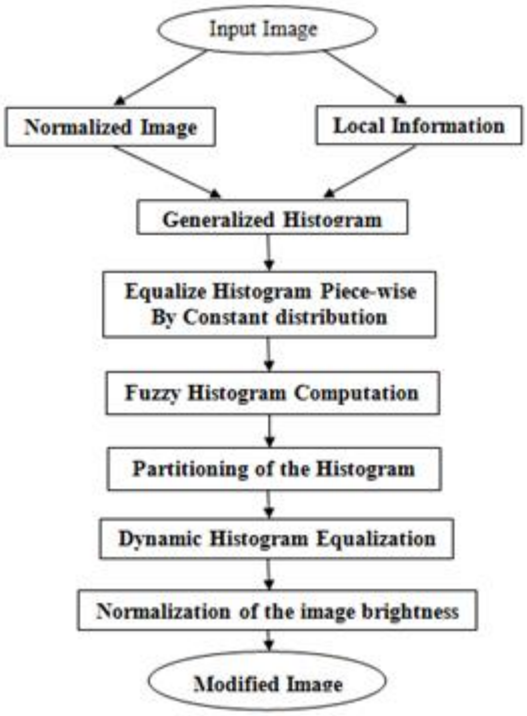

Figure 2. Flow chart of proposed method

Here we divided the process in three major sections 1.) Obtain Multi-peak GHE, 2.) Equalization of Image,3.) Fuzzy based dynamic HE implementation.

Multi-peak Generalized HE

In starting steps multi-peak GHE approach is applied, wherein a generalized function will be defined as:

$g(x, y) = f(u(x, y), v(x,y))$ (1)

It depends on intensities u(x, y), and on the local information v(x, y) of each pixel (x, y). It is described as p(g(x, y)) is the density function, and it can be described in short

$p(g) = h(f(u,v))$ (2)

Intensity of any image (u(x,y)) can be obtained by normalizing the original image I(x,y). Laplacian, Sobel functions give the edge value of image(local information). The control on grey level is achieved with range [−0.5, 0.5] of value v(x, y).(Eq.(3)).

$$v(x,y) = \left(\frac{V(x,y)-V_{min}}{V_{max}-V_{min}}\right)^{\beta} \quad (3)$$

With β=enhancement factor, and β=[0,1]. If β>1, it will be de-enhanced. Then Eq. (2) can be re-written as

$$p(x,y) = u(x,y) + w(x,y)v(x,y) \quad (4)$$

Where $w(x,y) = \frac{\alpha}{I_{max}-I_{min}}$ (5)

with w = edge value. The change in the order of the gray levels can be controlled by controlling α (distortion factor). The higher the value of α , (α > 1) the better enhancement can be retained. After calculating p(x,y) for every pixel mapping of G(x,y) is done into [G_{min}, G_{max}] by using Eq.(6)

$$G(x,y) = G_{min} + (p(x,y) - p_{min})\left(\frac{G_{max}-G_{min}}{p_{max}-p_{min}}\right) \quad (6)$$

Where p_{max} = max {p(x, y) } and p_{min} = min {p(x, y) } and (x, y) ∈ A. G(x, y) calculated above is used to generate new histogram H (p) .

Image Constant distribution Equalization

1. Since the histogram *H(p)* is very noisy, we need to remove the noise, and we smooth the histogram by computing local minima. {pi, i = 1, . . ., m − 1}, and let

$p_0 = G_{min}$, $p_m = G_{max}$.

2. Histogram $H(p)$ of each segment is equalize solely $[pi, pi+1]$, where $\{i = 0, 1, . . . , m-1\}$. Here image is divided into two stage and some conditions are applied with some parameters named as gamma and delta, which are easily optimize to generate best effects on any gray scale image. Now enhanced image is obtained for next processing steps.

Generating Fuzzy Histogram

1. Suppose p(t) is modal value around t . A sequence of such p(t) value is base of Fuzzy histogram where t∈{0,1,….,B-1}. Fuzzy histogram is formulated by fuzzy number $\tilde{T}$ (a,b) of grey value T(a,b).

$$p(t) \leftarrow p(t) + \sum_a \sum_b \mu_{\tilde{T}(a,b)t}, s\epsilon[c,d] \quad (7)$$

Where $\mu_{\tilde{T}(a,b)t}$ is the triangular fuzzy membership function defined as

$$\mu_{\tilde{T}(a,b)t} = max\left(0,1 - \left(\frac{|T(a,b)-t|}{4}\right)\right) \quad (8)$$

and [c,d] is the support of the membership function. Statical value in fuzzy histogram controls the ambiguity in the grey level better than classical histogram giving flat and even histogram. Thus Fuzzy histogram best fit for this application.

Histogram Partitioning

In the valley portion histograms sub-sections are obtained and local maxima point serves the partitions. Besides better brightness preservation, the histogram peaks are not re-mapped. Also the contrast is increased.

Detection of Local Maxima: The central difference operator is used to calculate the first and second derivative of Fuzzy histogram , which is a discrete data sequence. (S. D. Chen and A. R. Ramli 2003)

$$p'(t) = \frac{dp(t)}{dt} \triangleq \frac{p(t+1)-p(t-1)}{2} \quad (9)$$

For t^{th} intensity level Fuzzy histogram p(t) with p'(t) as his derivative(1^{st} order).

As we know that the approximation error increases if we calculate 2^{nd} order derivative from 1^{st} order derivative. So we use central difference operator (K. Wongsritong et al 1998).

$$p''(t) = \frac{d^2p(t)}{dt^2} \triangleq p(t+1) - 2p(t) + p(t-1) \quad (10)$$

For t^{th} intensity level Fuzzy histogram p(t) with p''(t) as his derivative(2^{nd} order).

The local maxima point , when p'(t) crosses zero and p''(t) achieves negative value, is achieved simultaneously (N. S. P. Kong and H. Ibrahim (2008) .

$$t_{max} = t\forall\{p'(t+1) \times p'(t-1) < 0. p''(t) < 0\} \quad (11)$$

However, at the same time perfect zero crossings is not seen at discrete values. In such , valley is searched for maxima location. The points with the highest model value among the neighbouring pair is selected for maxima.

Creating Partitions: Suppose the dynamic range of fuzzy histogram is $[T_{min}, T_{max}]$ with (r+1) intensity levels for local maxima, be denoted by discrete sequence$\{q_0, q_1, .., q_n\}$. The (r+1) sub-histograms are represented after divisions are $\{[T_{max}, q_0], [q_0+1, q_1], \ldots [q_n+1, T_{max}]\}$

Dynamic Histogram Equalization of the Sub histograms

The individual equalization of sub-histogram with spanning function is done on each sub-histogram. At first new dynamic range mapping is done and then equalization is performed. The two stages are a) dynamic range mapping b) histogram equalization.

Mapping Partitions to a Dynamic Range: The mathematical operation done for new dynamic range are as follows:

$$spn_t = hi_t - lo_t \quad (12)$$

$$fact_t = spn_t \times log_{10} M_t \quad (13)$$

$$ran_t = \frac{(B-1) \times fact_t}{\sum_{s=1}^{r+1} fact_s} \quad (14)$$

For t^{th} input sub-histogram, hi_t, lo_t is highest and lowest intensity value, M_t = Sample space of pixels. spn_t = Dynamic range of the input sub-histogram , ran_t = Dynamic range of the output sub-histograms For t^{th} part of sub histogram dynamic range is given by ran_t as

$$upper_t = \sum_{s=1}^{t-1} ran_s + 1 \quad (15)$$

$$lower_t = \sum_{s=1}^{t} ran_s \quad (16)$$

The two end points have some irregularities, where $[upper_1\ lower_1] = [0, ran_1]$ and

$$[upper_{r+1}, lower_{r+1}] = [\sum_{s=1}^{tr+1} ran_s, B-1] \quad (17)$$

Equalizing each Sub-histogram: The global histogram equalization process is applied on each partition of the histogram. The remapping value for t^{th} sub-histogram is calculated as in [11].

$$z(u) = upper_t + ran_t \sum_{s=srt_t}^{u} \frac{p(s)}{M_t} \quad (18)$$

Where z(u)= input image new intensity level for u^{th} intensity level , p(s) = Fuzzy's s^{th} intensity level value histogram, $M_t = \sum_{s=upper}^{lower} p(s)$ = population count in the t^{th} partition of the fuzzy histogram.

Normalization of Image Brightness

The normalization process checks the difference between input and output image mean brightness for dynamic histogram equalization and discards the difference in brightness in output image.

The grey level value of image 'g' obtained after BPDFHE at pixel location (x,y) having m_i = input image mean brigtness and m_o = mean brightness after DHE. Then

$$g(x,y) = \frac{m_i}{m_o} f(x,y) \quad (19)$$

The honesty of brightness preservation is in ensuring the brightness of input and output image to be nearly equal. So this is done by the given process. A better image is resulted with maximum brightness same as input image.

Simulation Results

In this section, proposed method BPFMGHE, together with histogram equalization (histeq), image adjustment (imadjust), adaptive histogram equalization (adaphisteq), GHE and BPDFHE applied on a gray scale image mall_new.jpg for comparison (with the help of MATLAB). The results are given in Figures. 3 and their histograms in Figure 4.

Image enhancing algorithm performance is evaluated and compared on the basis of image brightness and contrast parameters. Here we observe this from the histogram of the input and output images and we use Image Quality Measurement tools (IQM): their entropy (Table 2) and PSNR (Table 1) to justify the effect of proposed method. Figure 3(a) indicates original image (grayscale image) for expressing details image histeq is shown in figure 3(b) however improving image contrast but image brightness has increased drastically after performing histeq operation on image; due to which high luminosity details are washed out. No significant improvement is seen with imadjust function (figure 3(c)) in gray scale distribution, For detailed perception Adaphisteq (figure 3(d)) is good but it has undesirable increased brightness giving non uniform and abrupt gray scale distribution. Figure 3(e) shows the output of GHE, contrast enhancement is not noticeable here, Preserved brightness with lost neutrality in image is shown by BPDFHE output (figure 3(f)) ,best image.

Table 1. Comparison of Enhancement Techniques on the basis of PSNR

	HE	Imadjust	Adapthisteq	GHE	BPDFHE	BPFMGHE
Obj._1	21.65	21.37	17.25	6.04	*33.22*	*30.98*
Obj._2	11.92	16.52	19.21	8.28	17.34	*22.55*
Obj._3	15.21	17.11	23.55	6.79	*23.76*	*21.52*
Obj._4	12.68	16.02	14.72	9.14	26.69	*29.92*

Table 2. Comparison of Enhancement Techniques on the basis of Entropy

	HE	Imadjust	Adapthisteq	GHE	BPDFHE	BPFMGHE
Obj._1	5.98	7.55	7.93	7.67	7.39	*0.0218*
Obj._2	5.77	6.07	7.28	6.69	5.97	*0.0008*
Obj._3	5.40	6.23	7.07	6.42	6.01	*0.0460*
Obj._4	5.95	6.88	7.82	7.51	6.84	*0.0225*

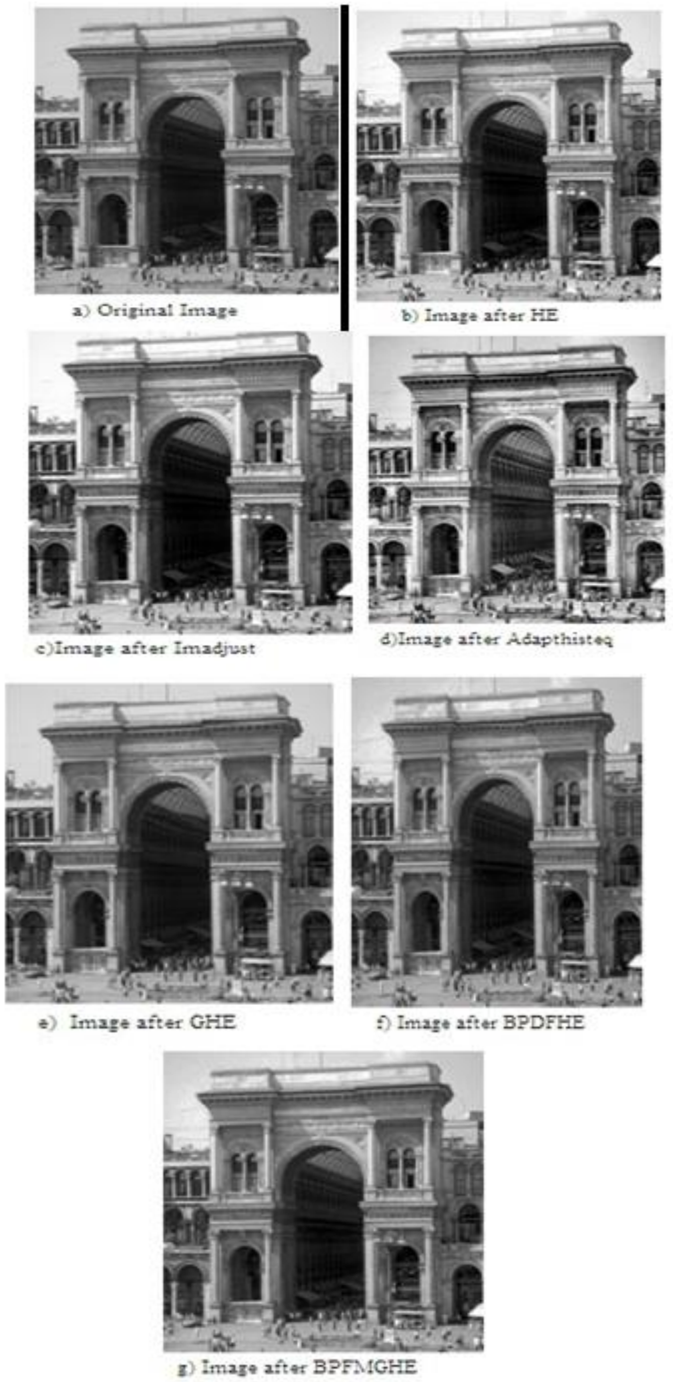

Figure 3 a) Original Image, b) Image after HE, c)Image after Imadjust d) Image after Adapthisteq e) Image after GHE, f) Image after BPDFHE, g) Image after BPFMGHE. [Image Used: mall_new.jpg]

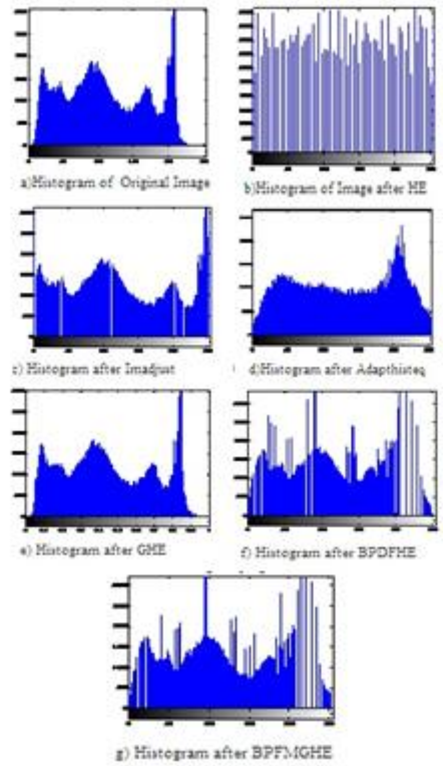

Figure 4 Histogram of a) Original Image, b) Image after HE, c) Image after Imadjust d) Image after Adapthisteq, e) Image after GHE, f) Image after BPDFHE, g) Image after BPFMGHE. [Applied on mall_new.jpg]

So for the above defects, proposed method have some factors (alpha and beta) which we optimize to obtain output image with best contrast improvement , less brightness variation and with uniformity in gray distribution, shown in figure 3(g). This concept is performed on more than ten images, and we found approximately same results, here we are showing outputs of a single gray scale image "mall_new.jpg".

Conclusion

An improved version of BPDFHE is proposed here which gives better brightness preservation with good contrast enhancement and lower artefact which we observed by better response on entropy and PSNR. We compare it with Histogram equalization (histeq), Image Adjustment (imadjust), Adaptive Histogram Equalization (adaphisteq), images enhanced by GHE and images enhanced by BPDFHE. According to the Image Quality Measurement (IQM) tools results shown in Table 1 and 2 we observe that the Entropy of proposed method BPFMGHE is comparatively very less than other Image enhancement techniques and there PSNR either high or approximately equal to the PSNR obtained by BPDFHE.

The proposed method also makes the change of the order of gray levels of original image completely controllable by values of alpha and beta; which make it more suitable for consumer electronic products where preserving the original brightness is essential and here we provide the freedom of selecting appropriate gray level.

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