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"Contrast enhancement using SHE, BHE, RMSHE and NOSHE with Entropy and EME"

Khamar Sabha S[1], Usha H.N[2], Mithun B.N[3], Prathibha G.C[4]

Assistant Professor, Dept of TCE, A.P.S.C.E, Bangalore[1,2]

Assistant Professor, Dept of ISE, A.P.S.C.E, Bangalore[3,4]

Abstract: Histogram equalization (HE) or projection is the well known method for the image enhancement because of its simplicity and is the base for advanced algorithms. Mainly there are two branches: global and local HE. In the global histogram equalization the entire image is equalized at a stretch where as in local histogram equalization the image is divided into sub-blocks and HE is carried for each block. In this paper, the image is segmented first. Number of sub-block is based on size of image and also sub-blocks are taken such that they are not overlapped. Then HP is done individually on each sub-block following this each sub-block is related to three of its adjacent sub-blocks by certain weight. This is to enhance the local details as well as to overcome the blocking effect. The algorithm is implemented using MATLAB and from results it can be shown that it enhances the image without any blocking effects also local details are enhanced. So it well suits for consumer electronics.

Keywords: Histogram equalization, Contrast enhancement, Local histogram equalization.

I. INTRODUCTION

Contrast enhancement is considered as an image processing both for images and videos, it can increase the image contents for human perception and recognition and improve the image visual quality. In addition, it is also helpful in pre-processing method to provide the high-performance images and videos to pattern recognition and other applications.

Histogram equalization (HE) can be categorized into two parts:

- Global histogram equalization (GHE)
- Local histogram equalization (LHE)

1.1 GLOBAL HISTOGRAM EQUALIZATION

GHE based algorithms compute the cumulative distribution function (CDF) by using the probability distribution function (PDF) of the original image, and accomplish the contrast enhancement by CDF mapping. The purpose of GHE is to make the PDF of the original image be distributed equally on the full greyscale range as shown in Fig.1

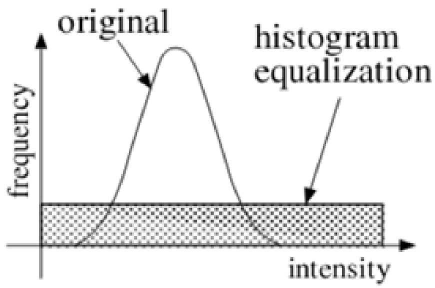

Fig.1 GHE Process

In practical the PDF in reality, the PDF cannot be ideally distributed because of the discrete characteristics of the digital image. Therefore, GHE based algorithms can only enhance the high-PDF gray easily
improved. scales, while the low-PDF ones cannot be easily improved.

Disadvantage

- Loss of Details due to combination and compression of Gray scale.
- They could also change the image brightness, leading to the wash-out effect.

1.2 LOCAL HISTOGRAM EQUALIZATION

In order to overcome the drawbacks mentioned above, LHE based algorithms are proposed, in which HE is executed in a finite region determined by a predefined sliding window. By moving the sliding window pixel wisely, the contrast enhancement could be completed until all the pixels in the image are successfully processed.

Advantage

- LHE based algorithms only equalize pixels in the finite region, thus they could effectively reduce the impact of other regions, and greatly enhance the local details.

Disadvantage

- They are much time consuming and complex in real-time applications.
- Take an image of 640×480 resolution for example, the quantity of implementing HE will come to 307200 times, so it is not easy to introduce LHE in the real-time processing systems.

II. NON-OVERLAPPED SUB-BLOCKS & HISTOGRAM PROJECTION

2.1 INTRODUCTION

Based on the requirement of real-time processing, Kimetal proposed a contrast enhancement using partially overlapped sub-block histogram equalization (POSHE) to deal with both the contrast enhancement and blocking effect. In this algorithm, it partitions the original image into numbers of sub-blocks, and then equalizes them in terms of partially overlapped manner, and finally averages

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the result based on certain weights. POSHE could be considered as a special version of LHE, thus it has all the features belonging to LHE besides its own. Namely it could well strengthen the local details as well as decrease the wash-out effect and blocking effect. Moreover, it is capable of accelerating the processing to achieve the real-time applications. However, if we inspect the results carefully, slight blocking effect still exists in the images though blocking effect reduction filter (BERF) operation is used.

No matter GHE, LHE or POSHE, the HE process is always the fundamental for these three methods. Therefore, HE based algorithms are not the optimal choices for contrast enhancement, especially when dim texture and tiny targets are what we concern most. Different from HE process, HP based algorithms work on the fact that zero-PDF gray scales sometimes exist in the original histogram, and they can enhance the contrast by redistributing the original gray scales uniformly onto the full greyscale range. The schematic diagram of HP process is shown in Fig. 2.

They could preserve the image brightness as far as possible, and avoid the annoying wash-out effect as well. HP based algorithms regarded as the global enhancement methods, could still bring about mutual influence among different regions, namely some parts of the image are improved, while others are not. Subsequently, a non-linear mapping based HP algorithm is proposed, which enhances the contrast by non-linearly adjusting the original histogram. It is indeed better than those traditional ones, but the non-linear mapping curve is not easily and automatically acquired in practical uses. In order to appropriately enhance the contrast and highly decrease the time consumption and complexity, we present the NOSHP to deal with these problems. It not only has efficient performance similar to the global methods like GHE and HP, but also owns detail enhancement of perfect visual perception similar to the LHE and POSHE.

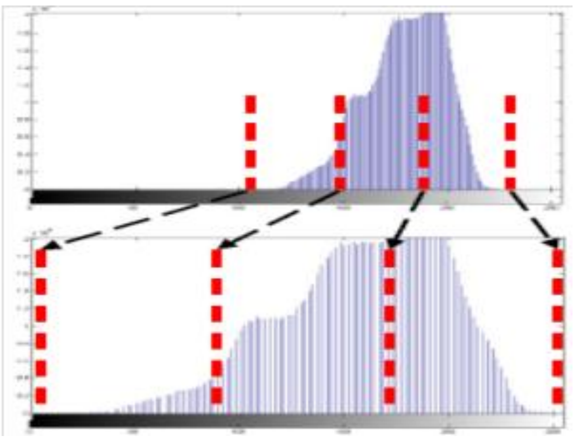

Fig.2 HP Process

2.2 NOSHP

To decrease the expensive computation as well as retain the feature of local detail enhancement, a non-overlapped sub-blocks based HE is presented. It partitions the original mage into numbers of non-overlapped sub-blocks, and then implements HE in every single sub-block individually.

Advantage

- The NOSHP implements only n1×n2 times of HP process to reach the final result.
- Visual perception of the image processed by NOSHP is superior to the others in terms of local detail perception and brightness preservation.
- The local details are well enhanced
- Blocking effect is successfully eliminated.

Disadvantage

- Inconvenient drawback we must face—the blocking effect as shown in Fig. 3

Fig.3 Non overlapped sub-blocks based HE Process

2.3 COMPARISON

Besides the subjective evaluation approves the effectiveness and performance of NOSHP, moreover we still need objective criterions to assess NOSHP in a scientific way. Here the entropy is employed. The discrete entropy is used to measure the content of an image, where a higher value indicates the image with richer details. Recently a new criterion for the contrast enhancement called measure of enhancement (EME) has been proposed. The EME approximates an average contrast by partitioning the image into numbers of non-overlapped sub-blocks, and then finding a measure based on the minimum and maximum gray values in each sub-block, and finally averaging them to generate the final result. The entropy and EME are shown in Table 1. The entropy of GHE is less than that of the original image. That is because the greyscale combination and compression occur after GHE. While the entropy of POSHE is much higher than that of the original image due to its great performance to the local details. The NOSHP algorithm we presented in this paper not only effectively preserves the brightness, but also successfully enhances the local details. Therefore, the entropy of NOSHP is the highest of all. The EME evaluation usually generates a higher value when there is larger variation of gray values in a sub-block.

Based on this conception, GHE and POSHE both achieve the high value. The EME value of NOSHP seems slightly lower than that of GHE and POSHE, but the local detail perception and the proper brightness are the best for the human visual perception.

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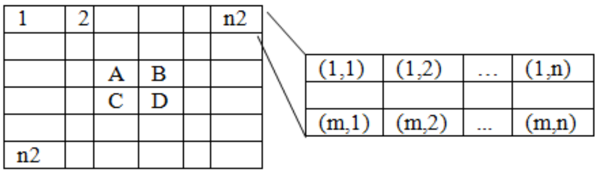
Table 1: Time consumption and objective assessment

	Original	HP	GHE	POSHE	NOSHP
HE(HP)Implementation	----	1	1	(2n1-1)×(2n2-1)	n1×n2
Entropy	4.667	4.667	4.104	5.315	5.525
EME	20.212	20.212	377.624	387.135	300.790

Under the consideration of time consumption and algorithmic flexibility, in this algorithm the image segmented into 4×4 to 8×8 sub-blocks is recommended. In our experiments, we segment the image into 4×4 & 8×8 sub-blocks for example.



Original image **Sub-block A**

III. ANALYSIS & SIMULATION

3.1 HISTOGRAM EQUILIZATION To enhance the image the transformation function used in histogram equalization is

$$pr(rk) = nk/MN \qquad k=0, 1, 2\ldots\ldots L-1$$

Where MN is the total number of pixel and nk is the number of pixel with intensity value being k.

The above equation indicates the pdf or histogram of the image.

The mapping or transformation function is given by

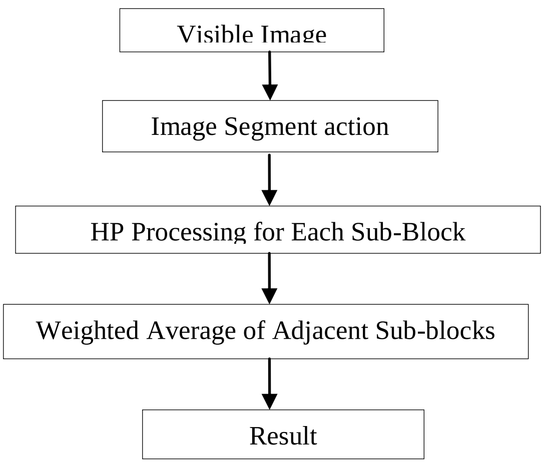
$$sk = T(rk) = (L-1)\sum_{j=0}^{k} pr(rk)$$

k=0, 1, 2……..L-1

This is nothing but a CDF function. The histogram equalization widens the dense regions and narrows the low pixel regions. So one disadvantage of histogram equalization is that it over enhances the high contrast images.

3.2 NON-OVER LAPPED SUB BLOCKS AND HISTOGRAM PROJECTION

3.2.1 Flow chart of NOSHP



3.2.2 Analysis

Consider the image of size M X N. The image is sub divided into blocks. Each is size mxn as shown below.

3.2.3 Algorithm Framework

A visible Image Processing: When the original image is M×N and each sub-block is determined to be m×n, then the quantity of sub-blocks in the image is n1×n2 (n1=M/m，n2=N/n) as illustrated in Fig. 4. The processing steps of NOSHR are as follows.

<u>Step 1:</u> Calculate the PDF of the original image and count the nonzero-PDF gray scales

$$PDFa(k) = \frac{p(k)}{pa} m$$

Where k=0, 1 … L-1

$$flaga(k) = \begin{cases} 1, pdfa(k) > 0 \\ 0, pdfa(k) = 0 \end{cases}$$

$$Ca(z) = \sum_{k=0}^{z} flaga(k)$$

z= 0, 1….L-1

Where pdfa(k) denotes the PDF value of k^{th} greyscale in sub-block A, pk and Pa

Depict the pixels of k^{th} greyscale and all the pixels in sub-block A respectively. Flag a(k) is a statistical flag for the k^{th} greyscale in sub-block A, of which 1 is for the nonzero PDF, and 0 is for the zero PDF. Ca(z) represents the cumulative function. Repeat this for all the blocks.

<u>Step 2</u>: The mapping function according to histogram equalization is,

$$Ta(z) = (L-1) * ca(z)$$
$$ca(z) = Ca(z)/Ca(L-1)$$

Where ca(z) =Ca(z)/Ca(255) is the normalization of Ca(z), and Ca(255) =1. The same operations are also executed in the adjacent three sub-blocks B, C, and D to acquire the corresponding mapping functions respectively.

Tb (z) =(L-1)*Cb(z)
Tc (z) =(L-1)*Cc(z)
Td (z) =(L-1)*Cd(z) where

Where Z=0, 1, 2, 3..........255

$$g(x,y) = \frac{\left[\begin{matrix} Ta\big(f(x,y)\big)(M+1-x)(N+1-y) + Tb\big(f(x,y)\big)(x)(N+1-y) \\ +Tc\big(f(x,y)\big)(M+1-x)(y) + Td\big(f(x,y)\big)(x)(y) \end{matrix}\right]}{(M+1)(N+1)}$$

Formula 1

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Step 3: To avoid the blocking effect, we relate the four adjacent sub-blocks by certain weights to decrease the brightness discontinuity on the block boundary, and the weights, which are related to the positions in the sub-block, can be obtained automatically. The final result can be expressed by the formula 1 as shown below.

Where fa(x, y) is the gray value at the position (x, y) in sub-block A and ga(x, y) is the output related to fa(x, y). The ga(x, y) is generated from fa(x, y) not only by the mapping function of sub-block A, but also the adjacent three sub-blocks. The formula we implement here is to reduce the irrational local contrast enhancement for every single sub-block, meanwhile strengthen the relationship of the neighbouring sub-blocks to achieve the integral improvement and local enhancement.

3.2 SIMULATION RESULTS

As shown in below figure the NOSHE removes the blocking effect and also local details are also enhanced. Compare to the standard histogram equalization. It also removes the washed-out effects.

The simulation is done for 4 and 8 blocks as it can be seen in the image there is a limit on the number of sub-blocks as the number of sub-block increases even this also suffers from over enhancement.

Even though blocking effect will be removed but it produces brighter pictures.

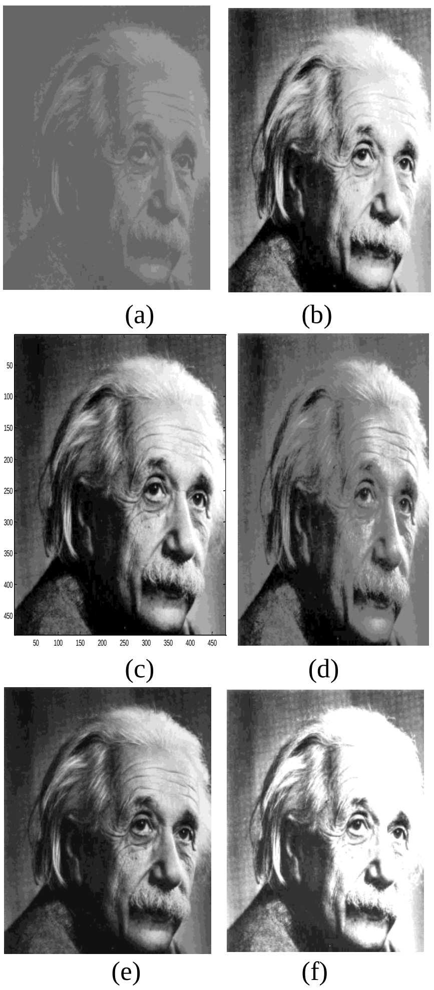

Figure 4. a) Original image b) SHE image c) BHE image d) RMSHE image using 8 sub block e) NOSHE image using 4 sub-block f) NOSHE image using 8 sub-blocks

Figure 4.a shows the original image. In Figure 4.b we can see that the SHE over enhances the original image but Figure 4.c BHE enhancement capacity is better than SHE also absolute mean error is less.

In Figure 4.d RMSHE washed out effects even though entropy is higher than BHE. In Figure 4.e NOSHE enhances better than all above mentioned algorithms also entropy is much higher which means that it retains more information. From Figure 4.f we can see that it enhances the local details such as cloud in the image but as the number of sub-blocks increases enhancing capacity reduces.

Comparison of all the above algorithms along with Entropy and Measurement of Enhancement(EME) is as shown in Table 2.

	SHE	BHE	RMSHE	NOSHE
ENTROPY	**5.6450**	**5.6525**	**5.4733**	**7.4434**
EME	**15.0278**	**10.0659**	**6.2932**	**23.0379**

Table 2. Comparison of all the above algorithms

3.3 CONCLUSION

The non-overlapped sub-block histogram equalization method enhances the low contrast images. It also overcomes the blocking effect and washed-out effect. The entropy of this method is higher than the standard SHE, BHE and RMSHE but there is a limit on number of sub-blocks as it increases the enhancement capacity decreases. This method can be used in consumer electronics and also to enhance images.

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