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로컬 히스토그램 명세화에 기반한 화질 개선

Image Enhancement Based on Local Histogram Specification

울럭벡 쿠사노브 · 이창훈†
Ulugbek Khusanov and Chang-Hoon Lee†

배재대학교 전자공학과
† Department of Electronic Engineering, Paichai University

Abstract

In this paper we propose an image enhancement technique based on histogram specification method over local overlapping regions referred as Local Histogram Specification. First, both reference and original images are splitted into local regions that each overlaps half of its adjacent regions and general histogram specification method is used between corresponding local regions of reference and original image. However it produces noticeable boundary effects. Linear weighted image blending method is used to reduce this effect in order to make seamless image and we also proposed new technique dealing with over-enhanced contrast areas. We satisfied with our experimental results that showed better enhancement accuracy and less noise amplifications compared to other well-known image enhancement methods. We conclude that the proposed method is well suited for motion detection systems as a responsible part to overcome sudden illumination changes.

Key Words : Contrast Enhancement, Histogram Specification, Local Region, Image Blending.

1. Introduction

Histograms are the basis for numerous spatial domain processing techniques. Histogram processing in images is used for image enhancement by modifying its histogram to obtain better visual appearance of an image. Usual methods include normalizing the histogram, spreading it uniformly over the gray levels as flat as possible. Very common and well known method is Histogram Equalization (HE). This method usually increases the global contrast by uniformly distributing intensities on the histogram. The method is useful in images with backgrounds and foregrounds that are both bright or both dark [1-5]. Histogram Specification (HS) is a special case of HE, it requires specifying the histogram of desired reference image to modifying the original image, detailed information in [1,6].

Most of the histogram processing methods [1-5] come with associated problems, such as computational requirements, noise amplification (overexposure of contrast) and application dependent despite being an efficient and simple. Since the global approaches would affect undesired parts of image, in the sense that pixels are modified by a transformation function based on the intensity distribution of an entire image. The solution for this problem is easily achieved by adapting local approaches [1,2]. For example, local histogram equalization (LHE) and automatic local histogram specification (ALHS) performs more accurate than global pairs, but it requires more computation time as they process small block-by-block base. In order to achieve computational efficiency while applying local approaches we introduce Local Histogram Specification (LHS) method which is applied for slightly larger local regions and adjacent regions overlap half of each other. And then HS is applied to each local regions separately.

The paper is organized as follows: Section 2 gives overall overview about general HE and HS methods. Our proposed LHS method are explained in Section. Experimental results and our concluding remarks appear in Section 4 and Section 5, respectively.

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† Corresponding author
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2. Histogram Processing

2.1 Histogram Processing

The histogram of a digital image with intensity levels in the range $[0, L-1]$ is discrete function $h(r_k) = n_k$, where r_k is the kth intensity value and n_k is the number of pixels in the image with intensity r_k where $k = 0, 1, 2, ..., L-1$. The right side of the figure 1 shows the histograms corresponding to these images. The horizontal axis of histogram plot corresponds to intensity values, r_k. The vertical axis corresponds to values of $h(r_k) = n_k$ or $p(r_k) = n_k / MN$ if the values are normalized, where M and N are the row and column dimensions of the image. The $p(r_k)$ is an estimate of the probability of occurrences of intensity level r_k in an image [1].

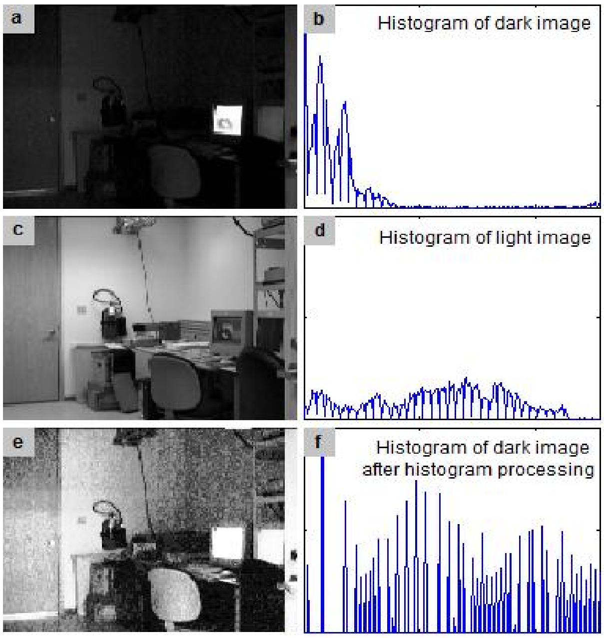

Fig. 1. Image histogram, (a-b) dark image and its histogram, (c-d) light image and its histogram and (e-f) histogram equalized image of (a) and its histogram

The dark images are tend to be that the components of the histogram are concentrated on the low (dark) side of the intensity scale while the components of the histogram of the light image are biased toward the high side of the scale, as shown in figure 1(b, d). Histogram processing is an intensity transformation that distributes the histogram components uniformly over whole intensity range, figure 1(f) and used for image enhancement. The most known histogram processing methods are Histogram Equalization (HE) and Histogram Specification (HS).

2.2 Histogram Equalization and Histogram Specification

Equation (1) produces an output intensity level s for every pixel in the input image having intensity r.

$$
\begin{aligned}
s_k &= T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j) \\
&= \frac{(L-1)}{MN}\sum_{j=0}^{k} n_j \qquad k = 0, 1, 2, ..., L-1
\end{aligned}
\tag{1}
$$

where $T(r)$ is monotonically increasing function that represents transformation between r and s in the interval $0 \le r \le L-1$ and $0 \le s \le L-1$ [1].

HE automatically determines a transformation function that output image has a uniform histogram. HS process the image to have histogram in desired shape by specifying the histogram of reference image. As a result, the PDF of the output image will be equal to the specified PDF [7].

Let $p_r(r_j)$ and $p_z(z_i)$ denote corresponding input and desired image probability density functions from their histogram respectively. If we equalize $p_r(r_j)$ and $p_z(z_i)$ by using equation (1) they both form identical uniform shape.

$$
s = T(r_k) = (L-1)\sum_{j=0}^{k} p_r(r_j) \tag{2}
$$

$$
G(z_q) = (L-1)\sum_{i=0}^{q} p_z(z_i) \tag{3}
$$

$$
z_q = G^{-1}(s_k) \tag{4}
$$

The following procedure explains process flow of HS:

1. s is obtained from given $p_r(r)$ of input image in equation (2).
2. Take transformation function from specified PDF in equation (3).
3. Obtain inverse transformation $z = G^{-1}(s)$ which mapping from s to z in equation (4).

3. Local Histogram Specification

3.1 HS for overlapping local regions

As it is shown in figure 2, the process flow starts from local area splitting after reference (I_r) and original images (I_o) are obtained. HS is used between local regions from reference and original images (ρ_{ref} and ρ_{org} respectively).

In our method local regions are rather large and operations are not pixel based. For example in our experimental results we selected local region size as 30x30. All local regions are overlapped completely by its adjacent regions, as it is shown in figure 3 with sample 6x6 square region. But in real applications the size can be extended even larger like 30x30. That's why losing computational efficiency coming from local operations is out of our concern. Splitting image into local regions

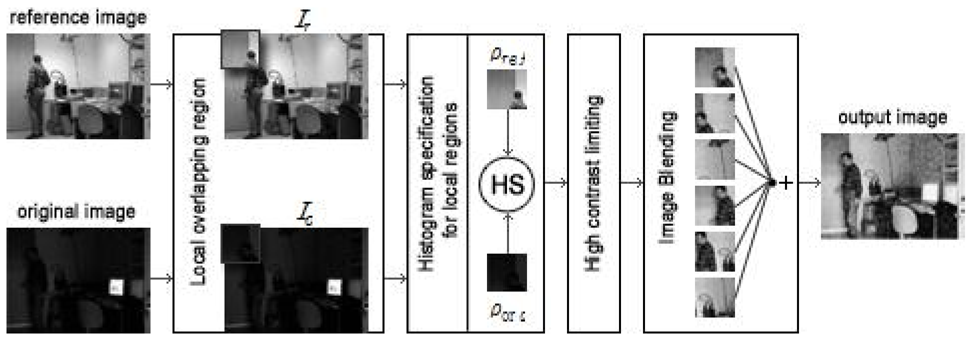

Fig. 2. Process flow of LHS

and using histogram processing separately for each of them means we are including position information which is very important.

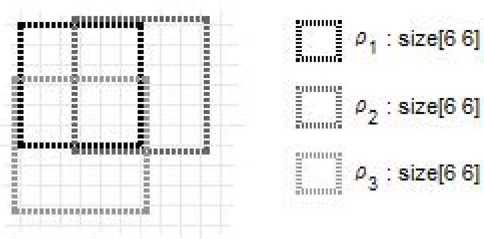

Fig. 3. Overlapping local regions

It is obvious that transformation in small fields is more accurate than in bigger fields, that's why we can claim that local transformations give better results compared to global approaches. Unlike local histogram equalization all pixels inside the local region are changed after histogram specification process and all overlapping local regions are fuse together in order to create seamless final image we use image blending method as described in process flow of our proposed method in figure 2. Since each local region overlaps half of its neighbor overall computation time for HS is just two times more than global approach. Because if spread all local regions it will be two times enlarged image.

3.2 High Contrast Limiting

If reference image is darker than original image, using ing general HS method may cause over-enhancement of unpredicted areas due to the existence of higher contrast regions in original image, for example monitor screen in figure 4(a). As a result, high intensity values of reference image will be transferred to unpredicted area which is totally wrong intensity transform, figure 4(c). As you can see the reference image in figure 4(a) has an over-enhanced area on monitor screen, i.e. intensity values here are more higher than at the same region of original image figure 4(b).

Introducing local HS method cannot solve the problem, because that wrong transform may appear inside the local block again. We proposed new technique to limit movement of high intensity values to unexpected areas by separating them into special regions where intensity values in dark image are greater than bright image. We defined I_r and I_o are reference and original images and they are described in figure 5(a) and figure 5(b) respectively. Let's say BW is a binary mask in figure 5(c) that can only take over-enhanced regions of reference image. The next step is to use HS separately for BW regions and the rest of the image, then fuse them together to get the final image given in figure 5(f). We can compare it with figure 5(e). We can achieve even more accurate intensity transformation if the same procedure goes for local HS, except fusing will be implemented in the final blending period in order to get clear seamless image.

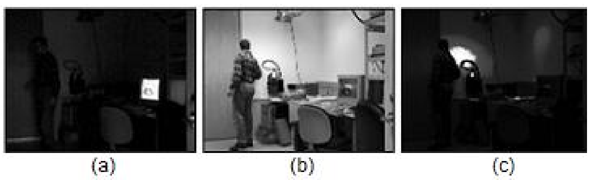

Fig. 4. HS, reference image (a), original image (b) and output image (c)

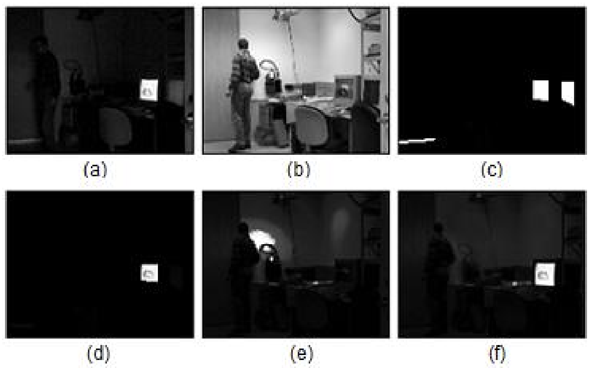

Fig. 5. Reference image (a), original image (b), binary mask (c), output image for separated mask (d), HS output without HCL (e) and HS output with HCL (f)

3.3 Image Blending for Overlapping Local Regions

Image blending is usually used in image stitching to make a seamless panoramic image by combining multiple images taken from different views. In our case we splitted one image into overlapping local regions and we enhanced each one separately. If we sum all pieces to make original image it comes back with visible seams. The difference of intensities appear on borders of each region and it is called boundary effect, figure 6(a). The simple answer is apply image blending over overlapping areas of adjacent local regions.

Fig. 6. Overlapping local regions; result of sum (a) and linear weighted blending (b)

There are many image blending methods, for example simple weighted blending, adaptive blending, histogram-based blending, feather-based algorithm, Laplacian pyramid image blending and Poisson image blending. Since we are working with one image dividing it into several local regions, we need computationally inexpensive model. So we preferred to use linear weighted blending method.

$$C(m,n) = C_L(a,b) \times \alpha + C_R(x,y) \times (1-\alpha) \qquad (5)$$

The intensity of the point C in overlapping region is calculated from equation (5), $C_L(a,b)$ is the intensity from left image with α weighting value and $C_R(x,y)$ is from right image with $(1-\alpha)$. The diagram of the weighted blending scheme are shown in figure 7.

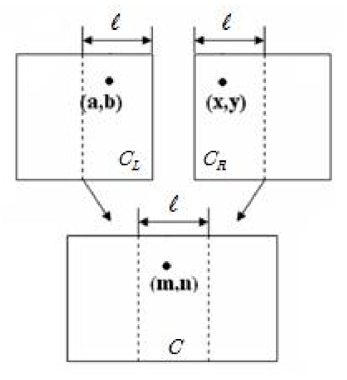

Fig. 7. Diagram of weighted blending scheme

The result of image blending can be seen in figure 6(b), as we use image blending at the final stage we will also fuse the result of HCL to get an output image.

4. Experimental Results

The reference and original images given in figure 8 are taken from video frame and they are sequential frames, yet under the illumination changes.

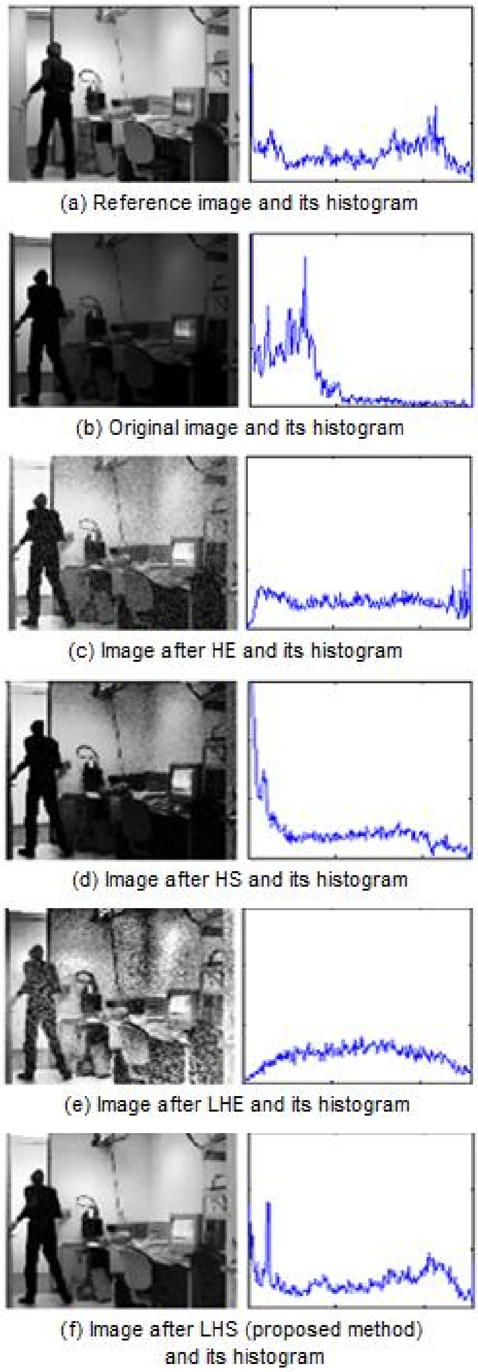

Fig. 8. Experimental results from video frame

The reference image is light and highly visible compared to original image that to be processed, i.e, enhance the visibility and lightness. Respectively, their histograms are different, the reference histogram is specific uniformly distributed over whole intensity region while original image has a narrow concentrated histogram, figure 8(a) and figure 8(b) respectively.

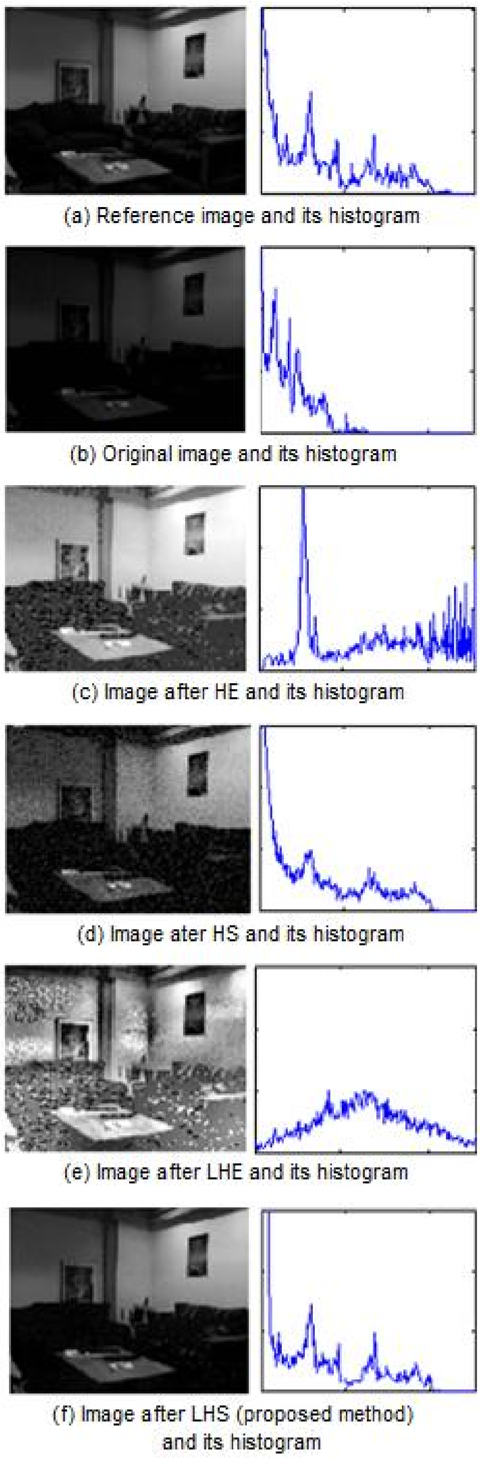

Fig. 9. Experimental results

Although HE modifies the original image's histogram uniformly histogram shape is not exactly similar and the result image from HE comes with visible noises, figure 8(e). Similar problems can be seen in HS and LHE, where LHE gives the worst result and its histogram is totally different from reference histogram, figure 8(c-e).

The proposed method gives very similar histogram shape respect to reference histogram and result is the best among others as presented in figure 8(f). Comparison of the result from our proposed method with HE, HS and LHE are noticeable, i.e. illumination is lighter, clear, much less noise and computation time is not in concern.

In figure 9 we took example reference image and orignal image without moving object intereference but again with illumination difference. The reference image and its histogram are given in figure 9(a) and the same for original image are in figure 9(b). Looking at the histogram of reference image we cannot find any similar shape from state of the art methods given results are illustrated in figure 9(c-e) except our proposed method in figure 9(f).

We take local region size around 30x30 and 40x40 as an optimal size, as we explained before. If reference and original image size gets smaller using LSE and HS methods are the same meaning, in this case general HS is preferred because of less computation time. So our proposed method has meaning when image sizes are large enough and reference image is provided.

5. Conclusion

In this paper we have proposed a novel local histogram specification method to enhance image contrast. The conventional histogram specification method is deployed for local partially overlapped regions of reference and original images. We also proposed high contrast limiting technique to prevent wrong high intensity transformation. At the final stage we applied linear image blending method to combine all enhanced local regions of original image.

We tested the proposed method in benchmark dataset along with general HE, HS and some other local approaches. And, experimental results demonstrated that the proposed method outperforms in accuracy.

We will aim to find a optimal local region size and increase computational efficiency by optimizing source code.

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저 자 소 개

울럭벡 쿠사노브(Ulugbek Khusanov)
2010년 : B.S. in IT from Tashkent University of Information Technologies, Uzbekistan
2011년～현재 : 배재대학교 대학원 전자공학과 석사과정

관심분야 : Image Analysis, Pattern Recognition, 3D Reconstruction, 3D Sensors
Phone : +82-42-520-5702
E-mail : pcubeki@pcu.ac.kr

이창훈(Chang-Hoon Lee)
1991년 : 연세대학교 전자공학과 공학사
1993년 : 연세대학교 전자공학과 공학석사
1999년 : Tokyo Institute of Technology 시스템과학 공학박사
2002년～현재 : 배재대학교 전자공학과 부교수

관심분야 : 지능시스템, 지능형 감시시스템, 로봇청각시스템, 임베디드시스템 등
Phone : +82-42-520-5702
E-mail : naviro@pcu.ac.kr