Optimal Global Contrast Enhancement Using Variable Size Block of Local Contrast Enhancement

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Abstract − **A conventional global contrast enhancement is difficult to apply in various images because image quality and contrast enhancement are dependent on image characteristics largely. And a local contrast enhancement one not only causes a washed-out effect, but also has a blocking effect. To solve these drawbacks, this paper derives an optimal global equalization function using variable size block based local contrast enhancement. The optimal equalization function makes it possible to get a good quality image through the global contrast enhancement. The variable size block segmentation is firstly executed using intensity differences as a measure of similarity. In the second step, the optimal global equalization function is obtained from the enhanced contrast image having variable size blocks. Conformed experiments show that the proposed algorithm produces a visually comfortable result image.**

Key words − ***global contrast enhancement; local contrast enhancement; optimal equalization function, block segmentation, variable size block***

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To acquire a good quality image by controlling brightness, various approaches for contrast enhancement have been developed. They can be categorized by global contrast enhancements and local contrast ones[1-4]. Global approaches improve image quality by extending dynamic range of intensity using the image histogram. Since GHE (global histogram equalization) uses the intensity distribution of the whole image, it may cause washed-out effect by changing the average intensity[5,6]. However, this method is difficult to apply in various images because image quality and contrast enhancement are largely dependent on image characteristics. To solve these problems, local histogram equalization techniques have been developed. POSHE (partially overlapped sub-block histogram equalization) technique proposed by Kim[2] is an example of overlapping sub-blocks. Its performance telling how much the blocking effect can be improved is determined by the size of the overlapping as well as the block size[7]. So selection of an optimal block size becomes an important problem which increases the computational time complexity[8]. This paper derives an optimal global equalization function using variable size block based local contrast enhancement. To solve drawbacks of above methods, a variable size block segment is firstly executed using intensity differences for measuremeat of similarity. Secondly, the optimal global equalization function is obtained from the enhanced contrast image having variable size blocks. In section 2, the variable size block segment algorithm is executed through the intensity similarity and the local contrast enhancement is applied to each of the variable size blocks. Section 3 derives the optimal global equalization function for the global contrast enhancement from the local contrast enhancements. In section 4, an improved performance of the proposed algorithm is proved by the experiment where it is compared with those of the conventional algorithms. Section 5 gives conclusions.

1 Local contrast equalization of variable size block

1.1 Split-merge segment algorithm

Local contrast equalization is based on the split-merge segmentation where the image is divided into regions of uniform intensity. Before local contrast equalization will be discussed, quadtree decomposition for the split-merge segmentation is stated.

The image is initially split into a certain number of blocks by cutting it alternately in horizontal and vertical directions. A variance of pixels in each block is measured to split the block. The splitting of

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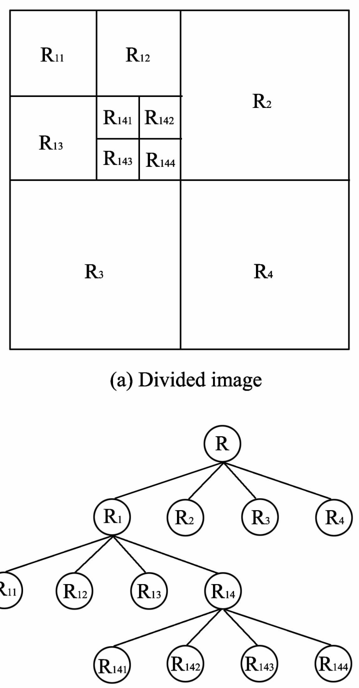
blocks goes on until not only the variance is smaller than the predefined threshold, but also the dimension of the block equals quad-regions of size 8×8. Empirically, the best result in terms of enhancing the local contrast was obtained using quad regions of minimum size 8×8. The splitting algorithm has a convenient representation in the form of quadtrees, in which each node has four exact descendants as shown in Fig. 1.



(a) Divided image

(b) Quadtree

Fig. 1 Images corresponding to the nodes of quadtree

Neighboring blocks under the same intermediate nodes are checked for possible merges, to establish whether the single merged block can be adequately approximated by a block in the reconstructed previous frame.

1.2 Local contrast enhancement methods

Histogram equalization techniques[1] acquire the scale factor from the normalized cumulative distribution of the brightness distribution of the original image and multiply this scale factor to the original image to redistribute the intensity.

An image is represented as a set of data, $X=\{X(i,j)\mid X(i,j)\in\{X_0, X_1, \cdots, X_{L-1}\}\}$, where each component may have one of L intensity levels. That is, $X(i,j)$ represents the normalized intensity of (i,j)th pixel in the image plane and X_k is the kth intensity level.

It is assumed that the number of blocks, which are given by the above sprit-merge segment algorithm, is N. To equalize the brightness histogram of a given image ${}^iX$ in any ith block, it is normalized first to obtain the probability density function (PDF) of the image, represented as

$$ {}^ip_x(X_k)=\frac{n_k}{i_n}, $$
$$ \text{for } 0\leqslant X_k\leqslant {}^in \text{ and } \sum_{k=0}^{L-1}{}^ip_X(X_k)=1, \qquad (1) $$

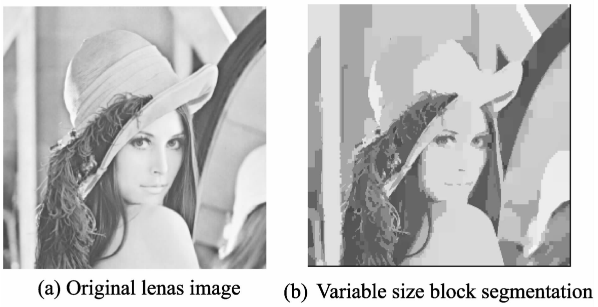
where ${}^in$ is the total number of pixels in ith block, n_k is the number that X_k appears in ${}^iX$ in ith block. To obtain a histogram equalization function, the cumulative distribution function of X_k is calculated first from probability density function using the following Eq. (2)

$$ {}^is_X=\sum_{k=0}^{L-1} iP_X(X_k)=1, \qquad (2) $$

where $k=0, 1, \cdots, L-1$ and ${}^iT(X_{L-1})=1$. ${}^is_k$ is the value of the cumulative distribution function at the kth intensity level in ith block. From ${}^is_k$, the histogram equalization function is obtained by multiplying the maximum gray level as

$$ {}^if_{HE}(k)={}^is_k\times(L-1). \qquad (3) $$

Fig. 2 shows an example of enhancing the local contrast of an image based on split-merge segment algorithm.



(a) Original lenas image (b) Variable size block segmentation

Fig. 2 Local contrast enhancement based on variable size block segmentation

In Fig. 2, the result image acquired by applying a local contrast enhancement where the original Lena's image with 512×512 pixels is divided by variable size blocks. Fig. 2 shows an extreme example of blocking effect generally occurring in a block-based contrast enhancement technique where the blocks are not connected smoothly. To reduce this blocking effect, some approaches divide the blocks so that the boundary pixels of the neighboring blocks are overlapped[1,2].

1.3 Global contrast enhancement using local contrast enhancement

Although partially overlapped block-based approach looks like a reasonable solution for the problems caused by global and local contrast enhancement approaches, its performance depends fairly on the size of block and the overlapping ratio between the neighboring blocks. To be considered as a visually comfortable image, a contrast enhancement scheme should remove blocking and washed-out effects while intensity is well distributed.

In this paper, taking the above conditions as the goal to achieve, a new global contrast enhancement scheme which uses a local contrast enhancement based on variable size block segmentation. The flow of the proposed algorithm is shown in Fig. 3.

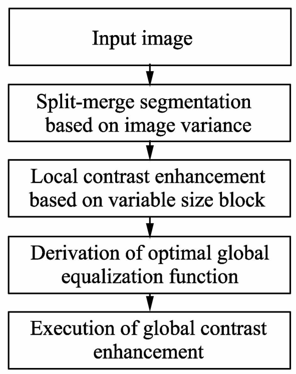


Fig. 3 Block diagram of the proposed algorithm

As shown in Fig. 3, the proposed algorithm largely consists of two steps, the local contrast enhancement is executed after dividing the original image into various size blocks in the first step. For every block, the local contrast equalization scheme is applied. Then, the optimal global equalization function is derived from the result of the local contrast enhancement and applied to the original image to produce the result image.

Once variable size blocks are equalized using a local contrast enhancement scheme, the global equalization function is derived from the locally equalized image. Supposing the number of variable size blocks in segmented image is Q, probability density function of a segmented image is given as

$$\begin{aligned} P_x(X_k) &= \frac{1}{Q}\sum_{i=0}^{Q}\frac{{}^{i}n_k}{{}^{i}n} \\ &= \frac{1}{Q}\left(\frac{{}^{1}n_k}{{}^{1}n}+\frac{{}^{2}n_k}{{}^{2}n}+\cdots+\frac{{}^{Q}n_k}{{}^{Q}n}\right) \\ &= \frac{1}{Q}({}^{1}P_X(X_k)+{}^{2}P_X(X_k)+\cdots+{}^{Q}P_X(X_k)), \\ &\text{for } 0 \leqslant X_k \leqslant 1 \text{ and } \sum_{k=0}^{L-1}P_X(X_k) = 1. \end{aligned} \quad (4)$$

In Eq. (4), Q is the number of the variable size blocks ${}^{i}n$ the segmented image and ^{i}n is the number of pixels in ith block. And ${}^{i}n_k$ is the number of pixels that have k level intensity in the ith block, and ${}^{i}P_x(X_k)$ is the probability density function of the ith block. Eq. (4) explains that global probability density function is determined by the average of the probability density functions for all blocks.

The cumulative distribution function of the segmented image to generate the optimal equalization function for global contrast enhancement is given by Eq. (5) according to Eq. (2) and Eq. (4).

$$\begin{aligned} s_k = T(X_k) &= \sum_{j=0}^{k}P_X(X_k) \\ &= \frac{1}{Q}\sum_{j=0}^{k}({}^{1}P_X(X_k)+{}^{2}P_X(X_k)+\cdots+{}^{Q}P_X(X_k)) \\ &= \frac{1}{Q}({}^{1}T_X(X_k)+{}^{2}T_X(X_k)+\cdots+{}^{Q}T_X(X_k)), \\ &\text{for } 0 \leqslant X_k \leqslant 1 \text{ and } T_X(X_{L-1}) = 1, \end{aligned} \quad (5)$$

where ${}^{i}T(X_k)$ is the cumulative distribution function of the ith block. In Eq. (5), the histogram equalization function for global contrast enhancement can be acquired. Since the cumulative distribution function is defined as the average of those of individual sub-blocks, the most suitable block equalization function can be determinee as the optimal equalization function. Fig. 4 shows the equalized image which is! applied the optimal global equalization function to the original image. It can be confirmed by eyes that the result image shows the best result that a blocking! effect is minimized without deterioration of the image quality.

Fig. 4 Result images acquired by applying the proposed method to the Rena's image

2 Experiments

Performance of the proposed algorithm is evaluated by comparing the edge images of the result images acquired by the proposed algorithm with thos by the conventional approaches, GHE and POSHE techniques. The reason of using the edge images for comparison is that the better result images may generate clearer edges if the contrast is well enhanced.

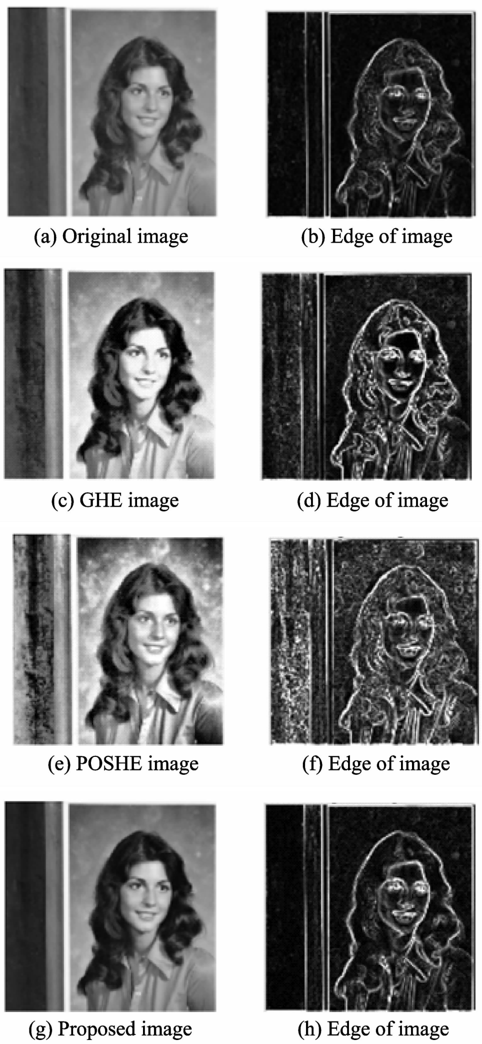


Fig. 5 Result images acquired by applying various contrast enhancement techniques to a person and simple background image

The test image consists of a person and simple background as shown in Fig. 5(a). Hair and background show a clear difference of brightness in the image. It is emphasized in the case of using GHE as shown in Fig. 5(c) whose edge image clearly shows the boundary between the person and the background as shown in Fig. 5(d). At the same time, the brightness difference among the pixels in the background is also emphasized so that the brighter pixels appear as noise in the result image. POSHE developed for reducing the block effect has produced the result image in Fig. 5(e) where the brightness difference is excessively emphasized over the whole image so that the background became so complex. One positive effect is that the contrast inside the face and clothes regions are improved so that they can be discerned clearly. The edge image of Fig. 5(e) shown in Fig. 5(f) has too much noise in the background and edges inside the face as expected. The result image acquired by using the proposed algorithm is shown in Fig. 5(g) where the local and global features are reasonably emphasized. Noise in background is minimized and the facial features appear clearer than in other images.

3 Conclusions

This paper derived an optimal equalization function for global contrast enhancement using the variable size block segment. To find the global equalization function, an image with variable size blocks is locally equalized for each block. The local enhancement functions are calculated from variable size blocks with other homogeneous specification. They make the global equalization function be optimal for global contrast enhancement. Through the experiment using the test images with lots of edge components, it has been proved that the proposed algorithm reduces blocking effect and washed-out effect, so a visually comfortable image are produced.

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