Shape Preserving Contrast Enhancement

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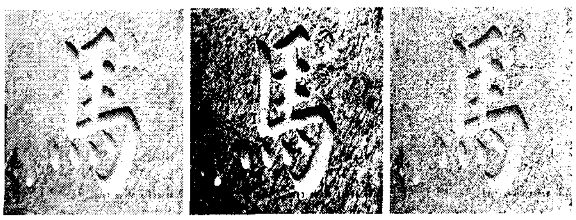
Abstract: In this paper, a new analytic approach for shape preserving contrast enhancement is presented. Contrast enhancement is achieved by means of segmental histogram stretching modification which preserves the given image shape, not distorting the original shape. After global stretching, the image is partitioned into several level-sets according to threshold condition. The image information of each level-set is represented as typical value based on grouped differential values. The basic property is modified into common local schemes, thereby introducing the enhanced effect through extreme discrimination between subsets. The scheme is based on stretching the histogram of subsets in which the intensity gray levels between connected pixels are approximately same In spite of histogram widening, stretched by local image information, it neither creates nor destroys the original image, thereby preserving image shape and enhancing the contrast. By designing local histogram stretching operations, we can preserve the original shape of level-sets of the image, and also enhance the global intensity. Thus it can hold the main properties of both global and local image schemes, which leads to versatile applications in the field of digital epigraphy.

Keyword: Histogram, Contrast Stretching, Segmentation, Locality, Level-sets, Digital Epigraphy

1. INTRODUCTION

Numerous techniques for enhancing the image contrast are used widely in image processing. Some of these techniques focus on stretching the dynamic range of important objects in image or global/local histogram equalization [2,3]. The most common way to improve the contrast of an image is to modify its pixel value distribution or histogram. Histogram modification, and in particular histogram stretching and equalization are basic and most useful techniques in image enhancement, and its description can be found in any book on image processing [1]. The technique modifies the histogram of an image so that the given image can be processed into new one, having more enhanced contrast. By stretching or uniformly distributing a histogram that has low-contrast levels with narrow band, one can obtain a desirable image. But the images captured under poor lighting conditions are not only too dark or too bright, but also the original shapes are contaminated [3]. Although input images are processed, the contaminated properties are as before maintained and represented in output images. Therefore it occasionally occurs that the resultant image is rather degraded comparing with the input image, inappropriate for visual inspection or simple observation. Fig. 1 shows one example. Fig. 1-(a) is the input image, (b) is the result of equalization, and (c) is of stretching.



(a) (b) (c)

Fig. 1 Results of histogram processing

Although histograms of generally used equalization and stretching have full gray level [0,1], the original image is on the contrary appropriate for visual inspection.

In application such as digital epigraphy [4-7], the image contrast is inherently low due to not only poor lighting environment, but also surface indiscrimination. Although, in order to represent the literal information, the letters are inscribed on the surface of rocks/metals, such that there occurs two regions; board and inscribed region, it is not easy to discriminate the literal information by visual inspection. The reason of indiscrimination is generally due to the property of surface, contamination and color-mixed. Fig. 2 shows one example.

Fig. 2 One image example of natural epigraph

The primary images acquired for processing is to be taken from squeezes [9], 'Korean Takbon [10]' or manual masking pre-process [8]. Fig 3. shows such three cases.

(a) squeeze (b) Takbon (c) manual mask

Fig. 3 Images from primary manual process

Because these are a secondary medium, the basic images contained in the image will necessarily be at least two stages removed from the originals that they represent. Mistakes can follow from inattention to the physical context and character of a document, which also happens in process of image capture by digital camera. Literal shape will be distorted or degraded. These are potentially serious limitations to the digitalization of epigraphic image. Wherever possible, therefore, documents of the inscribed face of an inscription must be preserved in shape. It may be that image enhancement techniques will eventually have to be used to provide acceptable representations of particularly difficult texts. This is an issue that is at present under consideration.

Thus contrast enhancement, holding the given shape, is most required to extract the literal information from the digitalized epigraphic image. For shape preserving contrast enhancement, the histogram property of the segmental region is to be maintained with the procedure of histogram processing. Within the histogram of input image, diverse histogram subsets of segments are included. If it is possible to partition the total histogram into sub-regional histograms that represent the typical values, we can stretch segmental histograms into the full intensity level. The main idea of this paper is such that; partition, grouping, sectional stretching and global continuous stretching.

2. BASIC FORMULATION

In case that the gray level histogram is composed of several discriminative dominant modes and pixels of input image can be grouped, the given image can be divided into sub-groups that represent the shape of objects in large image areas. It is quite simple to handle a situation in which the histogram of the gray values shows multi separable distribution with its distinct maxima. One obvious way to distinguish one region from another is to classify pixels as belonging to a bounded zone, $g_a \le h(x_i) \le g_b$, which exist between probability density maxima. There may be probability zero between these zones. Based on this property, the distinctive gray level of each sub-region is modified into a new representative gray value. These values, in general, are extremely selected, black and white. This approach is useful to extract the characters from the given image [1]. However, when intermediate gray values occur at the adjacency of the sub-regions, the probability density functions for the gray values of them may overlap. This overlap results in discordance. Some pixels of one sub-region will be recognized as another and vice versa. In less favorable case that shows non-minimum histogram, this method, on the contrary, may result in the contaminated out-image.

Therefore, in order to preserve the given image shape and also to have the contrast enhanced output-image, first of all, sub-region is to be defined. This idea is not the same approach as the segmentation. Sub-regions, in other word, are sub-sets of the given image domain, in which each one has its own pixel group of gray levels and histogram.

Let u be the given image with gray levels in the range $[g_1, g_2]$, h(u) the histogram of u, M_k the mean value of kth sub-region, and $f(x_i)$ the gray level of pixel x_i. The sub-region SR_k is defined as the set of pixels that satisfy the conditions bellow.

i) $SR_k = \{x_i | \nabla f(x_i) \le \alpha$ and $|M_k - M_l| \ge \beta\}$

ii) $\bigcup_{k=1}^{m} SR_k = R$

iii) SR_k is a connected region, k=1,2,..., m

iv) $SR_k \bigcap SR_l = \phi$ for all k and l, $k \ne l$

To be able to establish a regional discrimination in the image domain X, the region R of given (low contrast) image u is to be partitioned into n sub-regions, and connectivity between subsets is preserved. Each sub-region is assumed to be an equivalence relation as having the similar intensity gray level. In order words, for connected pixels x_i, x_j in a sub-region,

$$|f(x_i) - f(x_j)| \le \lambda_k \qquad (1)$$

where $f(x_i)$ is the gray intensity level at pixel and the integer λ_k, though small value, is the maximal integer of the difference histogram representing the frequency of the absolute differences between a pixel and its neighbors in kth sub-region, which is obtained by the formula, $\lambda_k = \sup\{\gamma_i | x_i \in X\}$.

3. LOCALIZED GLOBAL CONTRAST ENHANCEMENT

Intensity adjustment, in particular histogram stretching, is one of the basic and most useful operations which widen the dynamic ranges of the narrow portions of the original image into large or entire range, making the histogram fill the enough range. The operation is a particular case of point transformations that modify the contrast of an image within a display's dynamic range. In order not only to adjust the intensity, but also to preserve the shape, the operation of histogram stretching is to be limited within shape preservation. Sectional partitions are carried on by differentiate the two-dimension image values. The resultant values show the new image whose distribution functions is approximately uniform within the small range, and it follows that the basic information of total image can be grouped into the families of its binary shadows or approximately uniform level-sets. Each set has its representative functional value. In spite of histogram widening, stretched by local image information, it neither creates nor destroys the original image, thereby preserving image shape and enhancing the contrast.

3.1. Local intensity level

Suppose that the differences between intensity levels of pixels are sufficiently small and limited into tiny range, i.e., $\lambda_k \cong 0$, then the representative level of kth sub-region can be chosen as the mean value. The local mean, i.e., the sub-region component, of pixels $x_i(p,q)$ can be computed as bellow.

$$M_k = \frac{1}{p \times q} \sum_p \sum_q f\{x_i(p,q)\} \qquad (3)$$

Where M_k is the mean gray level of sub-region SR_k. Equation (3) means that a new intensity value is chosen in sub-region, so that the gray levels of this sub-region are all changed into its mean value. Applying this mean procedure to every sub-region SR_k, each pixel in SR_k is assigned a new gray level. This process is iterated by changing λ until either certain sub-region numbers are obtained or λ is incremented to a certain degree found from the local histogram.

The given image domain is sectioned into several segments whose representative gray levels are properly chosen. Let SL_k be the kth set of pixels of the local set, then its gray levels are modified into a constant. The input image domain X is the set of SL_k.

$$X = \{SL_k \mid x_i(p,q) \in SR_k\} \qquad (4)$$

The simplified constant is calculated in each subset, and the local histogram HL_k based on thus computed value is also constructed on one point of intensity horizontal axis. And a new image domain X_k is obtained, which has the same number of intensity levels as that of sub-regions. The relation between them is as bellow,

$$n(X) > n(X_k) \qquad (5)$$

where $n(A)$ is the number of elements in set A. X_k is the local representative of,the original image, where there exists some local contrasts such that new pixels $x_k \in X_k$. It should be noted that only M_k is used in SR_k and thus the noise is kept as small as possible.

3.2. Global histogram stretching

It can be described as that the set of objects obtained in X is the same as the set of objects obtained in X_k, if the objects in X_k has the connected components of intensity level sets as X. It means that the locality is preserved in the simple form of the family of shapes. Although the number of pixels is equal between X and X_k, the local representative will contain the reduced level patterns.

We are now reminded that our goal is to perform the contrast enhancement while preserving the connected components and level-sets. In order to achieve this goal, it need maximize the extremity of the intensity between shape-sets, expanding the local contrast differences uniformly to discriminate the locality, such that intensity adjustment is achieved for mapping an image's intensity values to a new range,

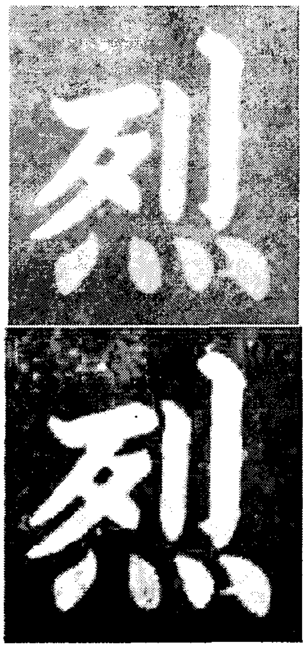
$$X_k[g_1, g_2] \rightarrow X_k[g_3, g_4] \qquad (6)$$

where $X_k[g_i, g_j]$ is the range of the gray level of X_k. The global histogram is obtained by synthesizing the local histograms. It follows that $X_k[g_3, g_4]$ has a uniformly expanding histogram for all connected components of all subsets. In this procedure, local histogram equalization is not recommended, because it will result in the contaminated image. The newly created intensity series construct the contrast enhanced image, where patterns will change stepwise, selecting a region of interest within an intensity image. By designing local histogram stretching operations, we can preserve the original shape of level-sets of the image, and also enhance the global intensity. It holds the main properties of both global and local image schemes.

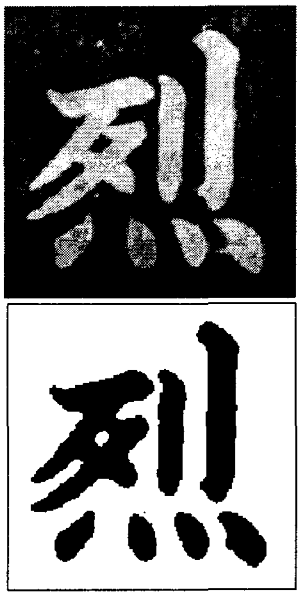
4. NUMERICAL EXPERIMENT

The test image with jpg type epigraphy will be used for demonstration. The gray scale consisted of 256 levels. In Fig. 4, we compare the out-image of the classical contrast enhancement with our result. Fig. 4(a) shows the original image captured by digital camera. RGB color image was transformed into gray scale. Fig. 4(b) shows the result of manual masking pre-process [8], which is more improved, although the edge is blurred. We can see that the given image domain is divided into two segments, literal information sector ( ) and backboard.

(a)



(b) (c)

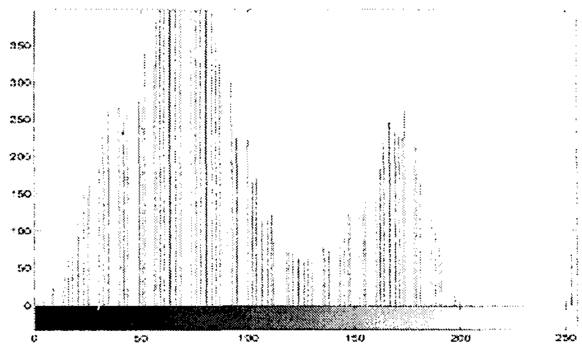


(d) (e)

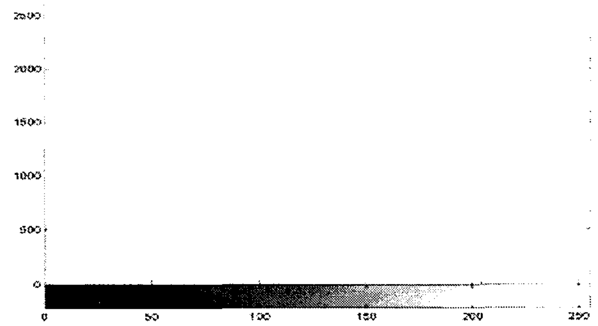
Fig. 4 Comparison between the classical histogram modification schemes with the new one proposed in this paper. (a) Original image. (b) Image obtained with masking pre-process. (c) Image obtained with the classical global histogram equalization. (d) Image obtained with histogram stretching. (e) Result of applying our scheme.

Fig. 4 (c) and (d) show the results of the classical contrast enhancement, histogram equalization/stretching. We see that new levels appear and the segments are contaminated. Fig. 4(e) presents the result of our algorithm applied to Fig. 4(b). The segmented two sectors are finely discriminated, and the contrast is improved while preserving the characters in the scene.

Results for the histogram analysis are presented in Fig. (5). Fig. 5(a) is the histogram of stretching of the masking pre-processed image (Fig. 4(b)). Fig. 5(b) shows the resultant histogram of the image applied by our scheme. We can see the image patterns are much simplified, having a few subsets.



(a)



(b)

Fig. 5 Comparison between the histogram of the global stretching scheme with one proposed in this paper. (a) Histogram of the global stretching scheme. (b) Histogram of my scheme.

5. CONCUSION AND REMARK

In this paper, a new contrast enhancement method, termed localized global approach, is proposed. The global and local techniques are basic and most useful operations, but for preserving the given shape, these are not proper, resulting in contaminated or degraded images. To improve enhanced condition, the indiscernible image domain is partitioned into many sub-regions according to grouping pixels of the approximately same gray intensity levels. Differential and discriminate approaches are used for segmentation. The final segmental sub-image is generated by thus differential process and mean-value comparison. Using the mean gray level of each subset, a localized global histogram is built, followed by a weighting histogram extreme stretching procedure. The proposed method shows better shape-preserved contrast enhancement results, both visually and quantitatively compared with previous techniques. This contrast enhancement is applicable to digital epigraphy, preserving and extracting the literal information. The enhanced image is formed by the new transformation function with desirable noise suppression on digitalized epigraphic image.

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