Iraqi Journal of Physics,2009 *Vol.7 , No.9 , PP. 13*-19

Gray-Scale Image Brightness/Contrast Enhancement with Multi-Model Histogram linear Contrast Stretching (MMHLCS) method

Faisel G.M. Al-Hamadi

Department of Computer Science, College of Science, University of Baghdad, Baghdad-Iraq.

Abstract

The purpose of this work is to enhance the contrast of a gray-scale image by using well known histogram stretching algorithm, but, in a new procedure. The most well known method is the histogram equalization because of its automatic procedure. However, the effect of brightness saturation will be appeared in some quasi-homogeneous region. This causes from the merging or adjacent gray level process for flattening the global histogram. Not only some lower brightness will be grouped together but also some higher brightness in order to uniforms the histogram distribution. Unlike the method of histogram linear contrast stretching the new wide histogram dynamic range can be assigned directly from the original narrow histogram dynamic range. However, the histogram of an image can be composed of many models of histogram. Different models can be represented with different objects. To enhance each models of histogram independently, the obtained result image will get better visual perceptibility than the global enhancement. The standard deviation of each model will be calculated and summed for providing the proportional of stretching range. The resultant image can be provided the higher efficiency in image segmentation or image classification. Therefore, this paper tries to carry out a method of the multi-model histogram linear contrast stretching. As each model of histogram can be detected by using the change of eight consecutive signs, each sign is obtained from the difference between two probabilities of adjacent gray level.

تحسين تمايز / لمعان الصور ذات التدرج الرمادي بأستخدام طريقة توسيع المخطط البياني ذو الأنماط المتعددة

فيصل غازي محمود

جامعة بغداد –كلية العلوم – قسم علوم حاسبات

الخلاصة

إن الغرض من هذا العمل هو لتحسين الصور الرقمية ذات التدرجات اللونية الرمادية باستخدام خوارزمية مد الهستوغرام المعروفة ، لكن، في إجراء جديد. إن الطريقةَ الأكثر شهرة هي مساواة الهستوغرام بسبب إجرائها الآلي. على أية حال، إن تأثير إشباع الإضاءة سيظهر في بعض المناطق شبه متجانسة. هذه ناتجة عن عملية الدمج أو تسوية المستويات الرمادية المتجاورة لتَسطيحِ الهستوغرام بأكمله . ليس فقط بعض مناطق الإضاءة الواطئة ستجمع مع بعضها لكن أيضا بعض مناطق الإضاءةَ العالية الأعلى لغرض تنظيم توزيع الهستوغرام. على خلاف طريقة مد الهستوغرام الخطية فان الطريقة المطورة تعتمد المدى الديناميكي العريض الجديد للهستوغرام الذي يمكن تعيينه بشكل مباشر من المدى الديناميكي الضيق للهستوغرام الأصلي. إن هستوغرام الصورة يمكن النضر إليه على انه مكون من عدة نماذج هستوغرام مختلفة. الأنماط المختلفة يمكن تمثيلها بأشياء مختلفة داخل الصورة. إن تحسين كل نموذج هستوغرام بشكل مستقل يؤدي إلى الحصول على صورة تعطي نتائج بصرية افضل من طريقة تحسين

الهستوغرام بأكمله مرة واحدة. الانحراف المعياري لكل نموذج سيحسب ويجمع لتزويد نسب لمدى المد. الصورة النّاتجة تعطينا كفاءة عالية في عمليات تجزئة أو تصنيف الصورة. إذن، هذا البحث يقوم بتنفيذ طريقة مد التمايز الخطي لهستوغرام متعدد النماذج. كل نموذج هستوغرام يمكن كشفه باستخدام التغير لثمان إشاراتِ متتاليةِ، كل إشارة يتم الحصول عليها من الاختلاف بين احتمالين متجاورين من المستويات الرمادية.

Introduction

Image enhancement, modifying the value of picture elements, is a classical method for improving the visual perception. Therefore, the processed image is more suitable than the original image for some applications. A digital image is encoded the picture element with L bits, the gray level of brightness will be varied from 0 to 2L-1. The ***probability*** of each gray level is defined by the following equation [1];

$$P(r_k) = n_k/N \quad \text{---------------------} \quad (1)$$

Where r_k is the k_{th} gray level, n_k is the number of pixel for the k_{th} gray level and n is the total number of pixels in the image. The distribution of all gray level probabilities is called histogram. If a digital image has a narrow dynamic range of histogram, the image will give low contrast. So the different objects in the scene will have almost the same brightness [2]. This will cause the difficulty in some applications such as object identification, an object classification, and etc. To improve the contrast for the image enhancement, the methods of histogram modification are always employed to spread out the dynamic range. The most well known method is histogram equalization. However, this method will be spread out the histogram and always reach the whitest and the blacked brightness. By consequently, the saturation of brightness will be appeared not only in quasi-homogeneous of low gray level but also in quasi-homogeneous of high-gray level. Unlike the method of histogram linear contrast stretching, the problem of brightness saturation can be avoided if the narrow range of original histogram is prosperously assigned to spread out.

Model detection

Since a histogram of image will be discontinued and fluctuated, therefore linear interpolation and smoothing method are applied to conquer these problems. For the smoothing procedure, nine consecutive of gray level probabilities are used to average. This average value is replaced by the central probability. The average value can be calculated as the following equation [1].

$$P_n(r_k) = \frac{1}{9}\sum_{i=1}^{9} P(r_{k-s+1}) \qquad \text{for } 5 \le k \le L-4 \quad \text{-- (2)}$$

To obtain the break points for discriminating each model in the histogram, the signs of two successive smooth probabilities will be calculated. The fluctuation of sign still exists. To smooth the sign, three consecutive signs will be considered for changing such as the following examples,

+ - + *change to* + + +
and - + - *change to* - - -

After the sign changing process is finished, the model detection is applied. To carry out a break point for distinguishing two adjacent models, the twelve consecutive signs are accounted. These four negative signs followed by eight positive signs define the break point. So the break point is the point that change from negative sign to positive sign.

Histogram linear contrast stretching

Since, the histogram can be composed of many models, which correspond to different objects in the image scene. To enhance each object or to increase the contrast of the scene, using equation (3) will linearly stretch each model:

$$y_{i,k} = \frac{(x_{i,k} - x_{\min,k})(y_{\max,k} - y_{\min,k}) + y_{\min,k}}{(x_{\max,k} - x_{\min,k})} \quad (3)$$

where $x_{min,k} = \overline{XK} - 2\sigma_k$ -------------- (4)

and $x_{max,k} = \overline{XK} - 2\sigma_k$ ----------------- (5)

where $\overline{XK}$ and σ_k are the mean and standard deviation of the k_{th} model respectively, $x_{min,k}$ and $x_{max,k}$ stand for the original narrow dynamic range of k_{th} model. For the histogram with p models, the value of $y_{min,1}$ is set to 0 and the value of $y_{max,p}$ is set to 255. The width of the stretching range ($y_{max,k}$ - $y_{min,k}$) will be obtained by the proportional of its standard deviation by using the following equation.

$(y_{max,k} - y_{min,k}) = \sigma_k/\sigma_r \times 256$ -------- (6)

where

$$\sigma_r = \sum_{k=1}^{p} \sigma_k \quad \text{----------------} \quad (7)$$

Implementation

Each pixel in a gray-scale image has brightness from 0 to 255, where 0 is black and 255 is white. A histogram shows the number of pixels with the various levels of brightness. The "0" value on the left of histogram shows the number of pixels that are black. The "255" value on the right of a histogram shows the number of pixels that are white. The histogram is *a probability distribution of the brightness levels.*

An image has low contrast when the complete range of possible values is not used. For example, the image shown in figure (1) only uses values 11 through 97 of the possible 0 to 255 range. Inspection of the histogram shows this lack of contrast.

The program automatically converts any color image of any Pixel Format to a pf24bit Pixel Format -- this avoids working with palettes. Each 24-bit color pixel has 8-bits of red, 8-bits of green and 8-bits of blue. A color image can be converted to a gray scale value by computing the "Y" value for each color

Pixel [3]:

$$Y = 0.299R + 0.587G + 0.114B \text{ ----} \quad (8)$$

This "Y" value is the grayscale component in the YIQ color space used in NTSC television. The weights reflect the eye's brightness sensitivity to the color primaries.

Other methods could have been used for this color-to-grayscale conversion.

Often, for convenience, an "Intensity" value is used:

$$I = (R + G + B) / 3. \text{ ----------------} \quad (9)$$

Once this "Y" value is computed, this "Y" value is then assigned back to each of the R, G, B components of the color pixel. RGB(i,i,i), where i = 0..255, yields a grayscale.

Working with gray-scale images in high-color or true-color environment allows the use of all values 0..255 without special API calls to establish a 256 gray-scale palette [4]. [By default, Windows reserves 20 of the 256 colors in 256-color display mode and a special API call is needed to "reclaim" 18 of the 20 colors. Two of the colors cannot be redefined, but these colors are "black" and "white" and they are needed for the complete 256-gray-scale palette anyway.]

When you process a gray scale image the program displays the number of shades of gray in the up between images. When you process a color image the program displays the original number of colors and the

resulting number of shades of gray in the up between images.
After reading the image file, the histogram frequency distribution is computed, as well as a number of other statistics. When a histogram has a single dominant peak, these statistics are often helpful in describing this peak.

The "range of interest" is computed from the histogram based on a percentage parameter. In the examples shown above, the 1% and 99% values are determined using the histogram. Normally this "range of interest" (Original Range) is stretched to the full 0 to 255 range to improve the contrast of the image. The percentage value, in effect, defines how many pixels are forced to be at 0 (black) and 255 (white). The below paragraph is part of source code of program (written with ***Delphi*** language):

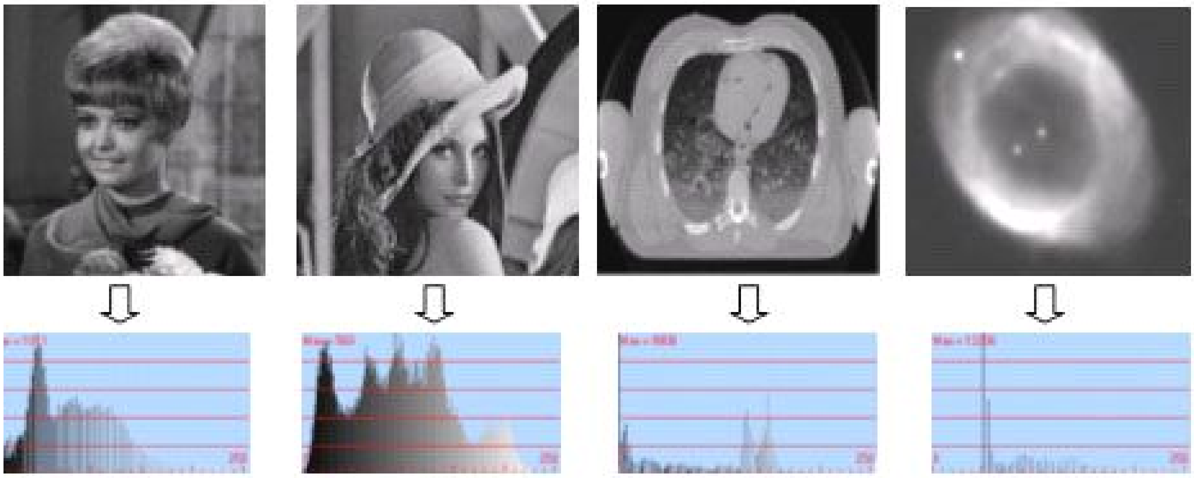
The StretchFactor, which is normally 1.00, is used as follows to compute a histogram ScaleFactor:

*StretchedRange := OriginalRange + ROUND(StretchFactor * (255 - OriginalRange));*
ScaleFactor := StretchedRange / OriginalRange;
The intensity of each pixel is inspected and re-assigned based on this ScaleFactor:
*NewIntensity := ROUND(ScaleFactor * (OldIntensity - OriginalRangeLeft));*
Each NewIntensity value is forced to 0 if below 0, and forced to 255 if above 255.

Experimental Result and Conclusion

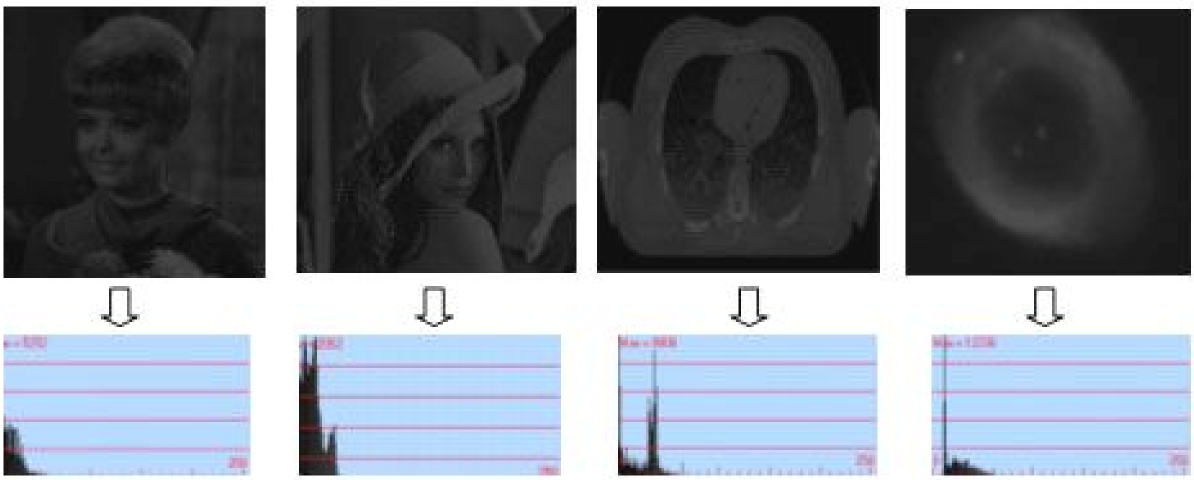
Histogram stretching is an effective way of improving the contrast of a gray-scale image. Histogram stretching a gray image by applying the technique shown here will result in an image with high contrast.

Real world images (Fig- (1)) used as an example with corresponding histogram of each image. Images in Fig- (1-a,b) are standard images while in Fig(1-d) is Planetary-Nebula (PN.) image. All these images have 8-bit (i.e., 1 byte). Fig- (2,3) illustrated same images if Fig- (1) but have Low contrast (i.e., have narrow gray-level range) obtained by using ***Adobe PhotoShop 4.0*** software. This can be achieved as follow:
(1) ***Open*** image, (2) Select ***Image*** from Task menu, (3) Select ***Adjust***, (4) Select ***Levels***, (5) Change only Brightness by dragging Level Value cursor down to decreasing contrast value.
The stretched histograms are obtained as shown in Fig- (4,5) and the corresponding result histogram. Fig- (4,5) are manifested the result of the multi-model histogram linear contrast stretching. The comparisons of images in Fig-(1) and Fig- (4,5) are clearly shown that the proposed method gave a high contrast and the boundaries of each region in the image are clearly emphasized. Therefore, the process of image segmentation and classification can be efficiently achieved from the restful image. Table-(1) shows the measurement criteria of all images in figures below.



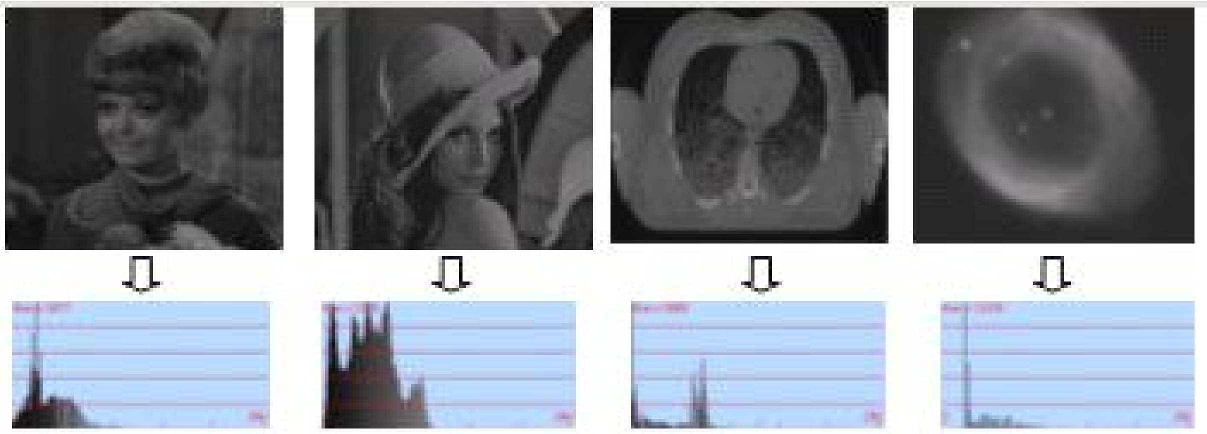
(a)Girl 65,536 pel (256×256 pel) (b)Lena 65,536 pel (256×256 pel) (c)Medical 93,600 pel (390×420 pel) (d)Astronomy 55,836 pel (282×836 pel)

Figure (1): Original images and it's associated Histogram



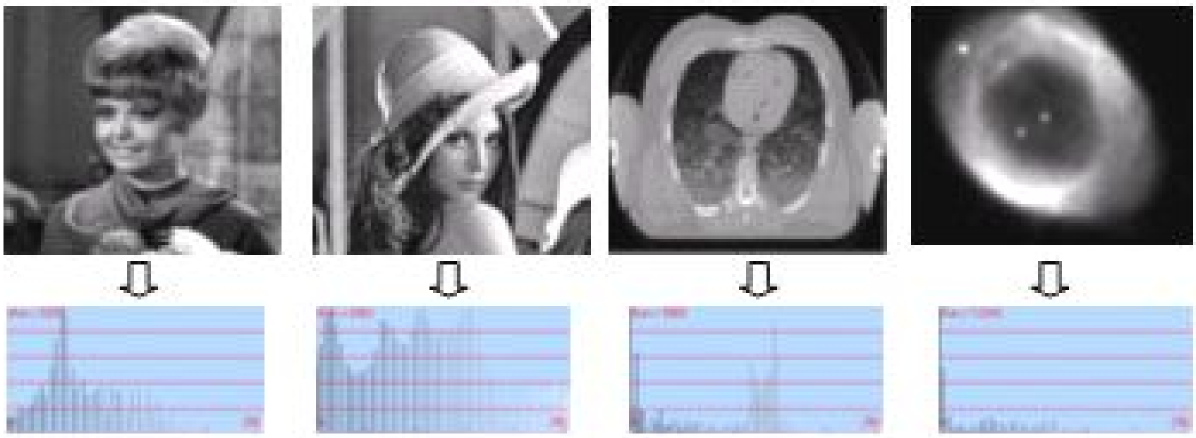
(a) Girl (b) Lena (c) Medical (d) Astronomy

Figure (2): Low contrast images (gray level range := 0 to 64



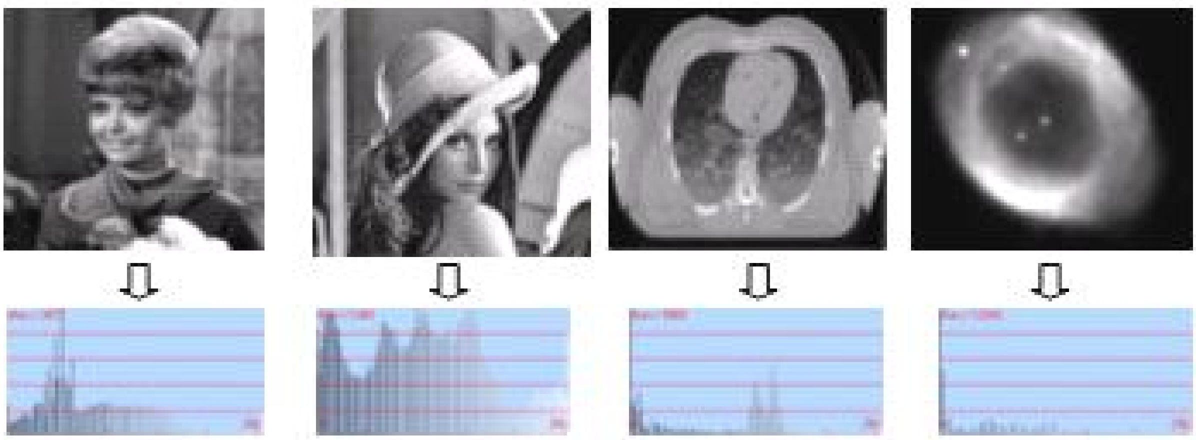
(a) Girl (b) Lena (c) Medical (d) Astronomy

Figure (3): Low contrast images (gray level range: = 0 to 128) and its associated Histogram



(a) Girl (b) Lena (c) Medical (d) Astronomy

Figure (4): Enhance images (gray level range: = 0 to 255) and its associated Histogram of fig- (2)



(a) Girl (b) Lena (c) Medical (d) Astronomy

Figure (5): Enhance images (gray level range: = 0 to 255) and its associated Histogram of fig- (3)

Table (1) : Measurement Criteria.

Image Name	**Min.**	**Max.**	**Mod.**	***Median***	**Mean**	**STD.**	**Max. Iteration**
1. Original (fig-(1))							
Girl	1	254	49	62	73.7	42.9	1911
Lena	3	242	92	97	99	52	569
Medical	0	255	0	125	93.6	63.6	9908
P.N.	40	248	52	92	102.3	51	12236
2. Low contrast , from 0 to 64 gray-level (fig-(2))							
Girl	0	64	12	16	18.5	10.7	5252
Lena	1	61	6	24	24.9	13.2	2062
Medical	0	64	0	31	23.5	15.9	9908
P.N.	10	62	13	23	25.6	12.8	12236
3. Low contrast ,from 0 to 128 gray-level (fig-(3))							
Girl	1	127	25	31	37.1	21.5	3677
Lena	1	61	6	24	24.9	13.2	1049
Medical	0	128	0	63	47	31.8	9908
P.N.	20	124	26	46	51.2	25.5	12234
4. Contrast Enhancement, from 0 to 255 gray-level (fig-(4))							
Girl	0	255	55	75	87.6	53.1	5252
Lena	0	255	15	107	111.4	67.3	2062
Medical	0	255	0	124	93.7	63.4	9908
P.N.	0	255	0	52	65.4	66.4	12284
5. Contrast Enhancement ,from 0 to 255 gray-level (fig-(5))							
Girl	0	255	56	71	86.1	53.1	5252
Lena	0	255	16	107	111.4	67.3	2062
Medical	0	255	0	126	93.7	63.4	9908
P.N.	0	255	0	52	65.4	66.4	12284

Reference

[1] John C. Russ, “The Image Processing Handbook, “ 2nd Edition, IEEE Press, 1994.

[2] R. C. Gonzalez and P. Wintz, “Digital Image Processing,” 2nd Edition, Addison-Wesley Publishing Co., Reading, Massachusetts, 1987.

[3] Yinpeng Jin , Laura Fayad and Andrew Laine, “Contrast Enhancement by Multi-scale Adaptive Histogram Equalization”, Department of Biomedical Engineering, Columbia University, New York, NY, 2001.

[4] Y. T. Kim, “Contrast Enhancement using Brightness Preserving Bi-Histogram Equalization,” IEEE Trans On Consumer Electronic, vol. 43, no. 1, pp. 1-8, Feb. 1997.