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Parameter Controlled Virtual Histogram Modification in Colour Image Enhancement

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Abstract **- A new hybrid image enhancement approach based on the parameter-controlled virtual histogram distribution method can enhance simultaneously the overall contrast and the sharpness of an image. The approach also increases the visibility of specified portions or aspects of the image whilst better maintaining image color. It driven by both global and local processes on luminance and chrominance components of the image. The approach was compared with other well-known image enhancement techniques. The experimental results have shown the superiority of the proposed approach.**

Keywords **- Image processing, image enhancement**

I. Introduction

Image enhancement is a method of improving the definition of a video picture by a computer program, which reduces the lowest grey values to black and the highest to white: used for pictures from microscopes, surveillance cameras, and scanners.

Surveillance videos have quite different qualities compared with other videos such as the videos for high quality entertainment or TV broadcasting. High quality entertainment or broadcasting videos are produced under controlled lighting environment, whereas surveillance videos for monitoring outdoor scenes are acquired under greatly varied lighting conditions depending on the weather and the time of the day. One of the common defects of surveillance videos is poor contrast resulting from reduced image brightness range. A routine examination of the histograms of the images from the videos reveals that some of the images contain relatively few levels of brightness, and some of the images have a type of histograms. In the type of histograms, a large span of the intensity range at one end is unused while the other end of the intensity scale is crowded with high frequency peaks, which is typically representative of improperly exposed images. Enhancement transformation is used to modify the contrast of an image within a display's dynamic range.

In existing methiods, Point-operation-based image enhancement includes contrast stretching, non-linear point transformation and histogram modelling are zero memory operations that remap a given input grey-level into an output grey-level, according to a global transformation. Non-linear point transformations which could improve visual contrast in some cases whilst clearly impairing visual contrast in other cases. In histogram modelling the original image is scaled so that the histogram of the enhanced image is forced to be some desired form such as uniform, exponential, hyperbolic or logarithmic. These methods have the disadvantage of treating the image globally only. Other classes of methods for image enhancement are approaches based on the Retinex theory[5], spatial operations and pseudo colouring. Pseudo-colouring methods artificially map the grey-scale image to a colour image, with the disadvantage that extensive interactive trials are required to determine an acceptable mapping scheme

Some histogram based approaches, such as dynamic range separate histogram equalization (DRSHE)[2], brightness preserving dynamic histogram equalization (BPDHE)[1] and gain-controllable clipped histogram equalization (GC-CHE) [3] have been developed in order to overcome some drawbacks of histogram equalization methods. Local enhancement methods have been developed based on the gray-level distribution in the neighbourhood of every pixel in a given image. A typical example of local enhancement methods is the adaptive histogram equalization (AHE), which has shown good results in medical imaging applications. However, AHE uses an enhancement kernel that is quite computationally expensive. Moreover, AHE may yield unsatisfactory outputs, e.g., images with noise artefacts and falsely enhanced shadows. Furthermore, all the aforementioned methodologies, except the pseud-colouring, only deal with grey-scale image enhancement, i.e., they only use luminance component of a colour image for colour image enhancement.

II. Principle of this Method

The proposed colour image enhancement method is a fast adjustable hybrid approach controlled by a set of parameters in order to take the advantages of point operations and local information driven enhancement techniques, in making effective use of the entire range of available pixel-values for both colour and luminance components of a colour image.

In surveillance videos/images, the luminance histogram of a typical natural scene that has been linearly quantized is, more often than not, highly skewed toward the darker levers; a majority of the pixels possess a luminance less than the average. In such images, details in the darker regions are often not perceptible. One means to enhance these types of images is a technique called histogram modification, where the original image is scaled so that the histogram of the enhanced image follows a desired distribution. Usually, a uniform distribution is used to create an image with equally distributed brightness levels over the entire brightness scale. The proposed enhancement technique is driven by both global and local processes to achieve not only effective improvement of overall contrast but also the significant enhancement of details in identified features/areas of interest of a colour image. The proposed method also aims at employing a much less time-consuming enhancement mechanism than those used by the existing methods.

Histograms are used to depict image statistics in an image interpreted visual format. Luminance histogram and component histogram both provide useful information about the lighting, contrast, dynamic range, and saturation effects relative to the individual colour components.

III. Intention of this Method

To find a monotonic pixel brightness transformation q=T(p) for a colour image such that the desired output histogram can not only meet specific requirements but also be as uniform as possible over the whole output brightness scale to fill in the full range of brightness values.

IV. Definitions And Notations

Let the pixel coordinates of a colour image is,

$$C \equiv \{c=(c1c2) | 1 \le c1 \le M, 1 \le c2 \le N\} \quad \text{------ (5)}$$

where M and N are the height and width of the image, respectively.

At each pixel coordinate,cεC,a multivariate Value

$$x_{RGB}(c)=[x_R(c),x_G(c),x_B(c)]^T \quad \text{---- (6)}$$

is used to represent the pixel in RGB (Red, Green, Blue) colour space at the current position.

A multivariate value

$$x_{YCbCr}(c)=[x_Y(c),x_{Cb}(c),x_{Cr}(c)]^T \quad \text{------- (7)}$$

is used to represent the pixel in YC_BC_R colour space.

For each RGB colour channel, each individual histogram entry is defined, respectively, as

$$h_R(i)=card\{c \mid x_R(c)=i, c\varepsilon C\}, \quad \text{---- (8)}$$
$$h_G(i)=card\{c \mid x_G(c)=i, c\varepsilon C\}, \quad \text{-----(9)}$$
$$h_B(i)=card\{c \mid x_B(c)=i, c\varepsilon C\}, \quad \text{----(10)}$$

where card{•} is the cardinality function, $0 \le i<K$, and K is a scale for a component of the colour image and, usually, 256. Second, the colour image is, some times, transformed from the RGB colour space or another colour space to the YCbCr colour space necessarily in the proposed image enhancement.

The luminance channel histogram of an image in the YCbCr colour space is defined as

$$h_Y(i)= card\{c \mid x_Y(c)=i, c\varepsilon C\}, \quad \text{-------(11)}$$

where all symbols are as defined in equations (8) to (10). The cumulative histogram for each RGB component and luminance component, Y, for the YCBCR colour space are defined by extending the definition of cumulative histogram from grey-scale image, respectively as

$$H_R(p)=h_R(i), \quad \text{-----------(12)}$$
$$H_G(p)=h_G(i), \quad \text{-----------(13)}$$
$$H_B(p)=h_B(i), \quad \text{-----------(14)}$$
$$H_Y(p)=h_Y(i), \quad \text{-----------(15)}$$

Where the input brightness value is [p0, pk] and p[p0, pk]. The cumulative histograms are monotonic no-decreasing functions with

$$H_R(K)= H_G(K)= H_B(K)= H_Y(K)=MN. \text{-----(16)}$$

A histogram for a greyscale image is calculated by summing up the number of all pixels which have the same brightness value and plotting the result in a diagram. Thus, for a standard 8bit (256 levels) image there are 256 columns with the extremities representing one black and one white.

Compared with the original image, an enhanced image with good contrast will have a higher intensity of the edges. Since a histogram of an image contains no information about the spatial arrangement of pixels in the image, luminance histogram and component histogram do not provide any information about the spatial distribution of the actual colours in the image. Since we are only interested in how to enhance the edge intensity without regard to its orientation, a linear differential operator, which is a local geometric information based operator, widely known as the Laplacian,

$$\Delta^2 x(c1,c2)=\partial^2 x(c1,c2)/\partial c1^2 + \partial^2 x(c1,c2)/\partial c2^2 \text{ ---(17)}$$

For a color image three histograms are calculated for the Red, Green and Blue components. PRICE displays the result in a single diagram by stacking the results of the color on each color: this way the total height of a column is the equivalent of the brightness in the equivalent greyscale image.

Histogram (almost perfect) of a greyscale gradient in an RGB image. Except the spike all levels are equal (a uniform gradient) and the thee RGB components are always equal, meaning they represent grey.The Laplacian operation is applied to each of the RGB channels, respectively.

Let

$$L_{RGB}(c) = |\Delta^2 x_R(c)| + |\Delta^2 x_G(c)| + |\Delta^2 x \quad \text{-----(18)}$$

If a histogram for an input colour image is $h_Y(p)$ and the input brightness value is [p0, pk], H, H1 and H2, are defined as follows:

$$H= \sum_{I=p_0}^{p_k} h_Y(i) \quad \text{------(19)}$$

$$H_1= w \sum_{I=p_{k10}}^{p_{k1}} h_{Yw}(i) \quad \text{-----(20)}$$

$$H_2= v \sum_{I_{=p}}^{p_k} h_{Yv}(i) \quad \text{-----(21)}$$

where p_{k1} and p_{k10} are in the range of $[p_0, p_k]$; $h_{Yw}(p)= h(p)$ if p is in the range of $(p_{k10}, p_{k1}]$, otherwise $h_{Yw}(p)=0$; w is a parameter with the default value of 2; v is a parameter with the default value set to 1.Using Cn = H/(H+H1+H2) as a normalization coefficient, a new virtual distribution function is defined as

$$\sum_{i=p_0}^{p} h_0(i) = Cn \left(\sum_{i=p_0}^{p} h_Y(i) + w \sum_{i=p_{k10}}^{p} h_{Yw}(i) + v \sum_{i=p_0}^{p} h_{Yv}(i) \right) \text{--}(22)$$

The desired pixel brightness histogram transformation T is defined as

$$q = T(p) = (q_k - q_0)/MN \int h_0(s)ds + q_0 \quad \text{------}(23)$$

The discrete approximation of the continuous pixel brightness transformation from Equation (23) is, therefore, given by

$$q = T(p) = (q_k - q_0)/MN \sum h_0(i) + q_0 \quad \text{-----------}(24)$$

Thus, the quantisation step-size is obtained as follows

$$\Delta q_i = (q_k - q_0)/MN \; h_0(p_i) = (q_k - q_0)/MN \; Cn(h(p_i) + w \, h_{Yw}(p_i) + v \, h_{Yv}(p_i)) \quad \text{-----}(25)$$

On the right-hand side of Equation (25), the second term is used to enhance contrast for a specified range [Pk10, Pk1];

$wh_{Yw}(i)=0$ if pi is not in the range of [Pk10, Pk1]; the third term, basically as the first term (input histogram of the image), is dependent on the image structure, though the parameter v can be adjusted. In most cases, v is fixed as 1, since the enhanced result is not very sensitive to the change of the v .

It is noted that the number of reconstruction levels of the enhanced image must be less than or equal to the number of levels of original image to provide proper intensity scale redistribution if all pixels in each quantisation level are to be treated similarly [6]. A hard-limit is needed to map the output image pixel values back into the display range [9]. However, the simple hard-limiting method is only suitable for an output image with only a few pixels whose brightness values are outside [q0, qk].

In order to avoid or to greatly reduce the brightness range of the output image, a rescaling constraint is employed using parameter t, which is introduced in the proposed method, to limit the maxima of q within t, and to smooth the enhancement contrast over the full brightness scale.

After the brightness contrast enhancement in the luminance channel, the output colour image is transformed back to the RGB colour space for display, since almost all hardware generally deliver or display colour via the RGB channels. The linear mapping of video signal from the RGB colour space to the YCBCR colour space , which is used by video and broadcasting television industry, is computed for the luminance component, Y, by [2, 21]

$$Y = 0.299R + 0.587G + 0.144B \; (21) \quad \text{----}(26)$$

where the luminosity (Y) is a function of R, G and B which are normalised to 1, and denoted as Y(R,G,B) . In order to determine the new borders of the output scaling range for the luminance channel (Y) we only need to find the corresponding Y values to the upper and the lower bounds of the RGB channels for the colour image. The values can be obtained from the output RGB histograms and the conversion from the RGB space to the YCBCR space[9, 21] is described as follows,

$$Ylow = \max\{ Ylow\text{-}red, Ylow\text{-}green, Ylow\text{-}blue \} \quad \text{-----------------}(27)$$

and

$$Yhigh = \min\{ Yhigh\text{-}red, Yhigh\text{-}green , Yhigh\text{-}red \} \quad \text{----------------}(28)$$

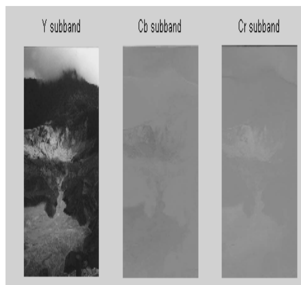
After the new output scaling range, q[Ylow, Yhigh], is obtained, the transformation (19) is to be redone with the new output scaling range, and the defect is removed of the image shown on its histogram as significant spikes at the tail ends, therefore the enhanced results show good contrast and much better colour maintenance as well.

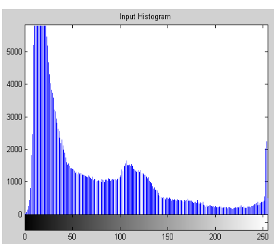
The number of reconstruction levels of the enhanced image in the proposed method is usually less than that of original image to provide proper brightness scale redistribution since all pixels in each quantisation level are to be treated similarly. For an original image with 256 levels of brightness, if the number of the brightness levels is not reduced too many, no significant degradation is perceived [. However, in some rare cases, if the original image have extremely low dynamic range with only few intensity values, the minimum brightness levels control will be applied in the proposed method by adjusting the parameters w and v, in order to ensure that the output dynamic range is not less than 70% that of the original to avoid over contrast enhancement. The threshold of brightness level for applying the control is set to 64. Since in some rare cases the last q of the transformation by Equation (28) is very large, a linear contrast stretch transformation is also applied in the proposed approach to ensure full use of the output brightness scale.

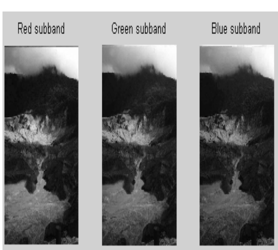
V. Working Experiment in Proposed Method

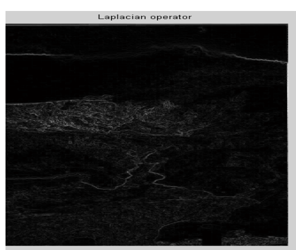
In the performance evaluation, the proposed method, which works as an automatic enhancement method using parameters with default values, is compared with four classical enhancement methods (linear contrast stretching, contrast reverse, gamma correction and histogram equalization and some recent developed histogram equalization based methods, such as DRSHE, BPDHE and GC-CHE using test images. The test image is a Mountain, with an image resolution of 500x362 pixels.The tested image Mountain was enhanced by the proposed method without output range boundary control. It is observed from the experimental results shown in Figs. that the proposed enhancement algorithm can effectively enhance the overall contrast and the sharpness of the test images. A significant amount of details that could not be seen in the original images has been clearly revealed. For the tested colour images, better results of the compared techniques, such as linear contrast stretching, contrast reverse, gamma correction and histogram equalization, are obtained by first converting the image to the Hue, Saturation, Intensity colour space and then applying the compared techniques to the Intensity component only. However, even this method does not fully maintain colour fidelity for the compared techniques [4], while the proposed technique show much better colour maintenance than other techniques.

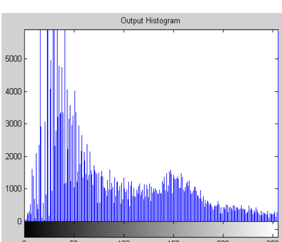
VI. Results











VII. Conclusion

A new hybrid approach based on a virtual histogram modification for colour image enhancement is proposed.it is a new way to integrate colour and brightness information extracted from salient local features, for global contrast enhancement.The special contribution of the proposed method are the output value scaling bounds control and output range boundary control for the enhancement mechanism to ensure the better maintenance of colour for the enhanced images. The proposed approach introduces the parameters to increase the visibility of specified features, portion or the aspects of the image. If the parameters are set up to default values, the proposed method will work as an automatic process.

In future work ,YCbCr colour space of an output image was converted into YUV colour space to improve the colour points in the image. This parameter controlled virtual histogram method was compared with exisisting enhancement methods and provided the better results.

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