# Colour Image Enhancement by Virtual Histogram Approach

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**Abstract** — *This paper introduces a new hybrid image enhancement approach driven by both global and local processes on luminance and chrominance components of the image. This 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 colour. The approach was compared with other well-known image enhancement techniques. The experimental results have shown the superiority of the proposed approach*[1].

**Index Terms — Image processing, image enhancement.**

## I. INTRODUCTION

Image enhancement, which transforms digital images to enhance the visual information within, is a primary operation for almost all vision and image processing tasks in several areas such as computer vision, biomedical image analysis, forensic video/image analysis, remote sensing and fault detection [2, 4]. For example, in forensic video/image analysis tasks, 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 [4], which is typically representative of improperly exposed images. The problem is how to approximate or reconstruct information that was lost because of the image having been captured under sub-optimal aperture or exposure conditions. Enhancement transformation to modify the contrast of an image within a display's dynamic range is, therefore, required in order to reveal full information contents in the videos, e.g., for forensic investigations.

First of all, the basic strategies are briefly reviewed for image enhancement. Point-operation-based image enhancement includes contrast stretching, non-linear point transformation and histogram modelling [3, 4]. They are zero memory operations that remap a given input grey-level into an output grey-level, according to a global transformation [2, 4, 9]. Non-linear point transformations, which could be expressed as $\boldsymbol{G}(j,k)=[\boldsymbol{F}(j,k)]^p$ where $\boldsymbol{F}(j,k)$ represents the original image, $\boldsymbol{G}(j,k)$ represents the output image and $p$ is the power law variable, have been shown to improve visual contrast in some cases whilst clearly impairing visual contrast in other cases [2, 3, 15]. In histogram modelling [10, 13, 17, 22, 24], 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 [18, 19]. These methods have the disadvantage of treating the image globally only. In order to differentiate between several areas of the image that may require different levels of contrast enhancement, an adaptive histogram modelling technique was proposed [16]. Images generated by the adaptive histogram modelling process, sometimes, is so harsh on the image visual appearance that an adaptive blurring of the window histogram was proposed [14] prior to forming the cumulative histogram as a means of improving the image quality.

Recently, some histogram based approaches, such as dynamic range separate histogram equalization (DRSHE)[6], brightness preserving dynamic histogram equalization (BPDHE)[7] and gain-controllable clipped histogram equalization (GC-CHE)[8] have been developed in order to overcome some drawbacks of histogram equalization methods.

Other classes of methods for image enhancement are approaches based on the Retinex theory [21, 23], spatial operations and pseudo-colouring. Spatial operations may suffer from enhancing excessively the noise in the image or conversely smoothing the image in areas that need to preserve sharp details [3] and these operations are also known to be time consuming. 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 [2].

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

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that is quite computationally expensive. Moreover, AHE may yield unsatisfactory outputs, e.g., images with noise artefacts and falsely enhanced shadows [1, 5].

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.

With a especial interest in surveillance video/image processing, 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.

The organization of this paper is as follows. Section II addresses the principles of the proposed image enhancement technique. Experimental results are presented in Section III. Final conclusions are drawn in Section IV.

## II. PRINCIPLE OF THE PROPOSED METHOD

In surveillance videos/images, the luminance histogram of a typical natural scene that has been linearly quantised 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. While histogram equalization applies a transformation that yields a close-to-uniform histogram for the relative frequency of the brightness-levels in an image, it only enhances the contrast for brightness values close to histogram maxima, and decreases the contrast near histogram minima [2, 12, 15]. If the image analyst is interested in certain parts or features of an image and the brightness of the parts or features of the image is not close the histogram maxima or, even worse, near the histogram minima, which happens often in surveillance video/image analysis, histogram equalization is helpless in the required contrast enhancement task. A linear-like or no-linear brightness stretching is only effective for an image where the histogram is narrow [2, 9], which is, unfortunately, not often the case in practical video/image analysis.

In order to meet the above particular practical demands and stringent requirements for forensic image/video analysis, biomedical image analysis and remote sensing, a new colour image enhancement method is proposed as follows. 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. With histogram, it is easy to determine certain types of problems in an image, such as if the image is properly exposed. Luminance histogram and component histogram both provide useful information about the lighting, contrast, dynamic range, and saturation effects relative to the individual colour components [4]. Therefore, in the proposed method the histogram of the enhanced colour image should not be saturated at one or both ends of the dynamic range or at least not bring new significant spikes at the tail ends in order not to introduce new poor exposure like defects in the image. In addition to a full use of the maximum possible dynamic range, colour component and local information can, certainly, make a contribution to the contrast enhancement. Ideally, an effective image enhancement technique devised using colour component and local information must not have or introduce very large spikes in the histogram of the enhanced image.

Therefore, the intention of the proposed method is 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 [9] to fill in the full range of brightness values.

First of all, definitions and notations are presented for introduction of the proposed enhancement method.

Let $C \equiv \{c=(c_1, c_2) \mid 1 \le c_1 \le M, 1 \le c_2 \le N\}$ denote the pixel coordinates of a colour image, where $M$ and $N$ are the height and width of the image, respectively. At each pixel coordinate, $c \in C$, a multivariate value $\mathbf{x}_{RGB}(\mathbf{c}) = [x_R(\mathbf{c}), x_G(\mathbf{c}), x_B(\mathbf{c})]^T$ is used to represent the pixel in RGB (Red, Green, Blue) colour space at the current position and a multivariate value $\mathbf{x}_{YC_BC_R}(\mathbf{c}) = [x_Y(\mathbf{c}), x_{C_B}(\mathbf{c}), x_{C_R}(\mathbf{c})]^T$ is used to represent the pixel in $YC_BC_R$ colour space [2, 21]. For each RGB colour channel, each individual histogram entry is defined, respectively, as

$$\boldsymbol{h}_R(i)=\text{card}\{\mathbf{c} \mid x_R(\mathbf{c})=i,\ c \in C\}, \quad (1)$$

$$\boldsymbol{h}_G(i)=\text{card}\{\mathbf{c} \mid x_G(\mathbf{c})=i,\ c \in C\}, \quad (2)$$

$$\boldsymbol{h}_B(i)=\text{card}\{\mathbf{c} \mid x_B(\mathbf{c})=i,\ c \in C\}, \quad (3)$$

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 $YC_BC_R$ colour space necessarily in the proposed image enhancement [2, 21]. The luminance channel histogram of an image in the $YC_BC_R$ colour space is defined as

$$\boldsymbol{h}_Y(i)=\text{card}\{\text{c} \mid x_Y(\mathbf{c})=i,\ c \in C\}, \quad (4)$$

where all symbols are as defined in equations (1) to (3). The cumulative histogram for each RGB component and luminance component, Y, for the $YC_BC_R$ colour space are defined by extending the definition of cumulative histogram from grey-scale image, respectively as

$$H_R(p) = \sum_{i=p_0}^{p} h_R(i), \tag{5}$$

$$H_G(p) = \sum_{i=p_0}^{p} h_G(i), \tag{6}$$

$$H_B(p) = \sum_{i=p_0}^{p} h_B(i) \tag{7}$$

and $$H_Y(p) = \sum_{i=p_0}^{p} h_Y(i). \tag{8}$$

where the input brightness value is $[p_0, p_k]$ and $p \in [p_0, p_k]$. The cumulative histograms are monotonic no-decreasing functions with

$$\mathbf{H}_R(K) = \mathbf{H}_G(K) = \mathbf{H}_B(K) = \mathbf{H}_Y(K) = MN. \tag{9}$$

Based on above definitions, the proposed enhancement method is described as follows.

Prominent image events, such as objects or a scene such as edges and contours, originated from local changes in intensity or colour, are highly important for visual perception and interpretation of images. It is thus naturally that the enhancement of edges has been an important task in image processing.

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, $\nabla^2 \mathbf{x}(c_1,c_2) = \frac{\partial^2 \mathbf{x}(c_1,c_2)}{\partial c_1^2} + \frac{\partial^2 \mathbf{x}(c_1,c_2)}{\partial c_2^2}$ may be used in order to enhance edge related area in colour images.

In colour images, the scale of brightness is 256 represented by 8-bit for most of images, whereas a true RGB colour space has distinct $2^{24}$ colours, with each colour component pixel represented by 8-bit. Therefore, the edge information is not only described by their luminance but also conveyed by their colour. In order to use information fully from both of brightness and colour perception, the Laplacian operation is applied to each of the RGB channels, respectively.

Let

$$L_{RGB}(c) = |\nabla^2 x_R(c)| + |\nabla^2 x_G(c)| + |\nabla^2 x_B(c)|. \tag{10}$$

Based on (10), we can define

$$S_{Lap} = \{ c \mid L_{RGB}(c) > T_{la},\ c \in C \}, \tag{11}$$

where threshold $T_{la} \in [1, 10]$, and the default threshold $T_{la}$ is set to 3.

Hence, $S_{Lap}$ is a set of pixel coordinates of an image, i.e., $S_{Lap} \subset C$. Each of the pixels with their coordinates in the set $S_{Lap}$ has a sum of absolute value of output of the pixel processed with a Laplace operator $\nabla^2$ (10) and the sum value is greater than $T_{la}$. We define

$$h_{Yv}(p) = \text{card}\{ c \mid x_Y(\mathbf{c}) = p,\ c \in S_{Lap} \}, \tag{12}$$

where the input brightness value are $[p_0, p_k]$ and $p \in [p_0, p_k]$. $h_{Yv}(p_i)$ can be treated as a special density function depended on the local feature of every pixel and the frequency of the brightness value of the pixels.

If a histogram for an input colour image is $h_Y(p)$ and the input brightness value is $[p_0, p_k]$, $H$, $H_1$ and $H_2$, are defined as follows:

$$H = \sum_{i=p_0}^{p_k} h_Y(i) \tag{13}$$

$$H_1 = w \sum_{i=p_{k10}}^{p_{k1}} h_{Yw}(i) \tag{14}$$

and

$$H_2 = v \sum_{i=p_0}^{pk} h_{Yv}(i) \tag{15}$$

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. Here, $H_1(p)$ is designed to suit special enhancement requirements for the image interpretation.

Using $c_n = \frac{H}{H + H_1 + H_2}$ as a normalisation coefficient, a new virtual distribution function is defined as

$$\sum_{i=p0}^{p} h_0(i) = c_n \left( \sum_{i=p_0}^{p} h_Y(i) + w \sum_{i=p_{k10}}^{p} h_{Yw}(i) + v \sum_{i=p_0}^{p} h_{Yv}(i) \right) \tag{16}$$

If $M$ and $N$ are the height and the width of an image, respectively, and the output brightness range is $[q_0, q_k]$, the desired output histogram can be approximated with (16) by its corresponding continuous probability density as follows:

$$MN \int_{q_0}^{q} \frac{1}{q_k - q_0} ds = \int_{p_0}^{p} h_0(s) ds \tag{17}$$

The left side of Equation (17) is the corresponding uniform probability distribution function. The desired pixel brightness histogram transformation $T$ is defined as

$$q = T(p) = \frac{q_k - q_0}{MN} \int_{p_0}^{p} h_0(s) ds + q_0 \tag{18}$$

The discrete approximation of the continuous pixel brightness transformation from Equation (18) is, therefore, given by

$$q = T(p) = \frac{q_k - q_0}{MN} \sum_{i=p_0}^{p} h_0(i) + q_0 \quad (19)$$

Thus, the quantisation step-size is obtained as follows

$$\Delta q_i = \frac{q_k - q_0}{MN} h_0(p_i) = \frac{q_k - q_0}{MN} c_n (h(p_i) + wh_{Y_w}(p_i) + vh_{Y_v}(p_i)) \quad (20)$$

On the right-hand side of Equation (20), the second term is used to enhance contrast for a specified range [$P_{k10}$, $P_{k1}$]; $wh_{Yw}(i) = 0$, if $p_i$ is not in the range of [$P_{k10}$, $P_{k1}$]; 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 $v$ (see Fig.1). Fig1.c and Fig1.d show the results of the tested image enhanced by the proposed method with different values of $v$. Through (20), it can be clearly seen how the output interval value between adjacent two brightness values is produced one by one and how the parameters make contribution to every output brightness level for contrast enhancement since human vision is very sensitive to the interval value $\Delta q$ [12, 20]. The default values of these parameters are: $P_{k10} = 0$, $P_{k1} = 30$ and $w = 2$. The parameters can be adjusted by an image interpreter to meet his or her specific requirements. For many cases, the proposed approach with the default values of the parameters works well without user intervention, as changes of the parameters do not affect the enhanced result very much (see Fig.1). Fig1.b Fig1.c and Fig1.d show the results of the tested image enhanced by the proposed method with different values of its parameters.

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 [12].

When the contrast of a dark area of an image whose histogram spans a broad range of the display scale is enhanced, the bright areas of the image may be out of the display range as a result of the above rescaling as defined by (19). When the contrast of a bright area of an image whose histogram spans a broad range of the display scale is enhanced, the dark areas of the image may also be out of the display range as a result of the above rescaling as defined by (19). Therefore, 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 [$q_0$, $q_k$].

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 $\Delta q$ within $t$, and to smooth the enhancement contrast over the full brightness scale. Consider a patch of light of intensity $I + \Delta I$ surrounded by a background of intensity $I$ and $\Delta I$ is actually similar to $t$ for human vision. Over a wide range of intensities, it is found that the ratio the $\Delta I/I$, called the Weber fraction, is nearly constant at a value of about 0.02[2], so the default value of $t$ is set to 3. The rescaling process also relieves further the undesired property of the traditional histogram equalisation technique, which tends to reduce contrast near histogram minima.

If an image with its histogram basically concentrated in a very bright region, the image can be first inversed. Then, the proposed method is applied and the resultant image is inversed back, to ensure above constraints being met and to work more effectively.

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.

Though the limitation of $\Delta q$ was applied, the output results, unfortunately in some cases, showed that a histogram/histograms of RGB channels was/were saturated at one or both ends of the dynamic range. The out-of-range output pixel values were mapped into the maximum or minimum values of the output scaling range and appeared on the histogram as significant spikes at the tail ends. They looked like what typically occurs in an underexposed or overexposed image, which is undesirable for improving visual quality of an image. In order to remove this defect, a more effective output range boundary control mechanism is further applied in the proposed method. The output range boundary control mechanism is introduced as follows.

The linear mapping of video signal from the RGB colour space to the $YC_BC_R$ colour space [2, 21], which is used by video and broadcasting television industry, is computed for the luminance component, Y, by [2, 21]

$$Y=0.299R+0.587G+0.144B \quad (21)$$

where the luminosity (Y) is a function of R, G and B which are normalised to 1, and denoted as $Y(R,G,B)$.

Obviously, according to (23), $\frac{\partial Y}{\partial R} \geq 0$, $\frac{\partial Y}{\partial G} \geq 0$, and $\frac{\partial Y}{\partial B} \geq 0$. Hence, $Y(R,G,B)$ is a non-decreasing monotonic function. 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 $YC_BC_R$ space[2, 15] is described as follows,

$$Y_{low} = \max\{ Y_{low\text{-}red}, Y_{low\text{-}green}, Y_{low\text{-}blue} \} \quad (22)$$

and

$$Y_{high} = \min\{Y_{high\text{-}red}, Y_{high\text{-}green}, Y_{high\text{-}red}\}, \quad (23)$$

where

$$Y_{high\text{-}red} = \min\{y| \; y = x_Y(\mathbf{c}) \wedge (x_R(\mathbf{c}) = 255) \wedge (h_R(255) - h_{red-old}(255) \geq s) \;\} \quad (24)$$

$$Y_{high\text{-}green} = \min\{y| \; y = x_Y(\mathbf{c}) \wedge (x_G(\mathbf{c}) = 255) \wedge (h_G(255) - h_{green-old}(255) \geq s) \;\} \quad (25)$$

$$Y_{high\text{-}blue} = \min\{y| \; y = x_Y(\mathbf{c}) \wedge (x_B(\mathbf{c}) = 255) \wedge (h_B(255) - h_{blue-old}(255) \geq s) \;\} \quad (26)$$

$$Y_{low\text{-}red} = \max\{y| \; y = x_Y(\mathbf{c}) \wedge (x_R(\mathbf{c}) = 0) \wedge (h_R(0) - h_{red-old}(0) \geq s) \;\}, \quad (27)$$

$$Y_{low\text{-}green} = \max\{y| \; y = x_Y(\mathbf{c}) \wedge (x_G(\mathbf{c}) = 0) \wedge (h_G(0) - h_{green-old}(0) \geq s)\} \quad (28)$$

and

$$Y_{low\text{-}blue} = \max\{y| \; y = x_Y(\mathbf{c}) \wedge (x_B(\mathbf{c}) = 0) \wedge (h_B(0) - h_{blue-old}(0) \geq s) \;\}, \quad (29)$$

where $h_{red\text{-}old}(i)$, $h_{green\text{-}old}(i)$ and $h_{blue\text{-}old}(i)$ are RGB histograms of the original colour image; $s=MNs_0$ is the number of the saturated pixels in the image and usually the same value is taken for both the upper and the lower bounds, with $s_0 \in [0.0005, 0.005]$ . The default $s_0$ is set to 0.002.

Using this formulation, the bounds of the new dynamic range do not depend purely on singular extreme pixels, but can be based on a representative set of pixels.

After the new output scaling range, $q \in [Y_{low}, Y_{high}]$, 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(see Fig 1).

The number of brightness levels which human can easily distinguish depends on many factors, such as the average local brightness. Consequently, a display, which avoids this effect, will normally provide at least 100 intensity levels within its display range [4, 15].

Generally speaking, 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 [4, 15]. 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[2, 15].

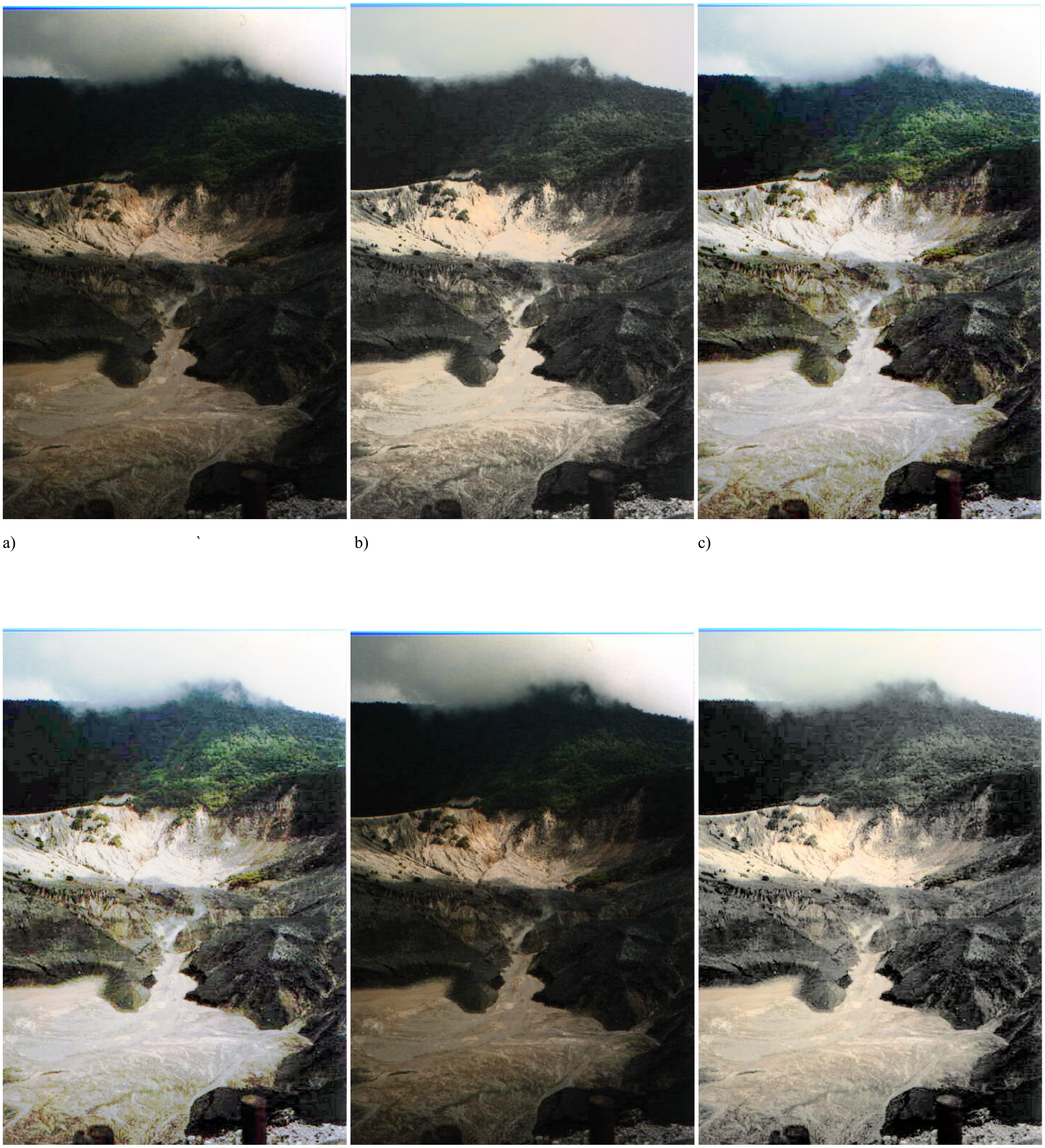
Since in some rare cases the last $\Delta q$ of the transformation by Equation (20) is very large, a linear contrast stretch transformation is also applied in the proposed approach to ensure full use of the output brightness scale.

Sometimes, an enhanced image serves as the input to a machine that traces the outline of the edges, and perhaps measures the shape and size of the outline. The image enhancement emphasizes salient features of the original image and simplifies the processing task for a data extraction machine. In this case, the proposed method can be applied directly to each of RGB channels, using the contribution from the colour and the luminance components for contrast enhancement. It shows clearly better performance in some of the test images, while introducing false colour in others.

## III. EXPERIMENTS

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 [2, 15, 20] and some recent developed histogram equalization based methods, such as DRSHE, BPDHE and GC-CHE using test images. The test images include well-known typical test images including *Mountain*, *Scene*, *Meat* etc, with an image resolution of 500x362 or 721x481 or 768x768 or 731x487 pixels.

The results enhanced by the proposed method with different values of its parameters are shown in Fig.1b, Fig.1c and Fig.1d. In Fig1b, the tested image *Mountain* was enhanced by the proposed method without output range boundary control. In Fig1.c, the tested image *Mountain* was enhanced by the proposed method with $t$=2 and $v$=1. In Fig1.d, the tested image *Mountain* was enhanced by the proposed method with $w$ =3 and $v$=2. It is observed from the experimental results shown in Figs. 1-4 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 [11] (see Fig.1f, Fig.3c and Fig.4c), while the proposed technique show much better colour maintenance than other techniques (see Fig.1c, Fig.1d, Fig.3b and Fig.4b). From the output images, these test images were enhanced by histogram equalization, the histogram equalization with over-enhanced parts of the images and highlighted blocking artefacts caused by image compression (see Fig.2c and Fig.4c). In terms of revealing the details in dark areas of images with a broad low histogram, the performance of the proposed approach is much better than the other image enhancement methods. The details in the dark areas of the test images, *Mountain, Light* and *Scene,* are much more visible than those in the original image while the colour of the images are better preserved. The linear stretching failed to make significant enhancement for these images.



a) b) c)

d) e) f)

**Fig. 1. The enhancement results for test image *Mountain*, a) original image, b) output of the proposed approach-1, c) output of proposed approach-2, d) output of proposed approach-3, e) output of modified linear stretching, f) output of histogram equalisation.**

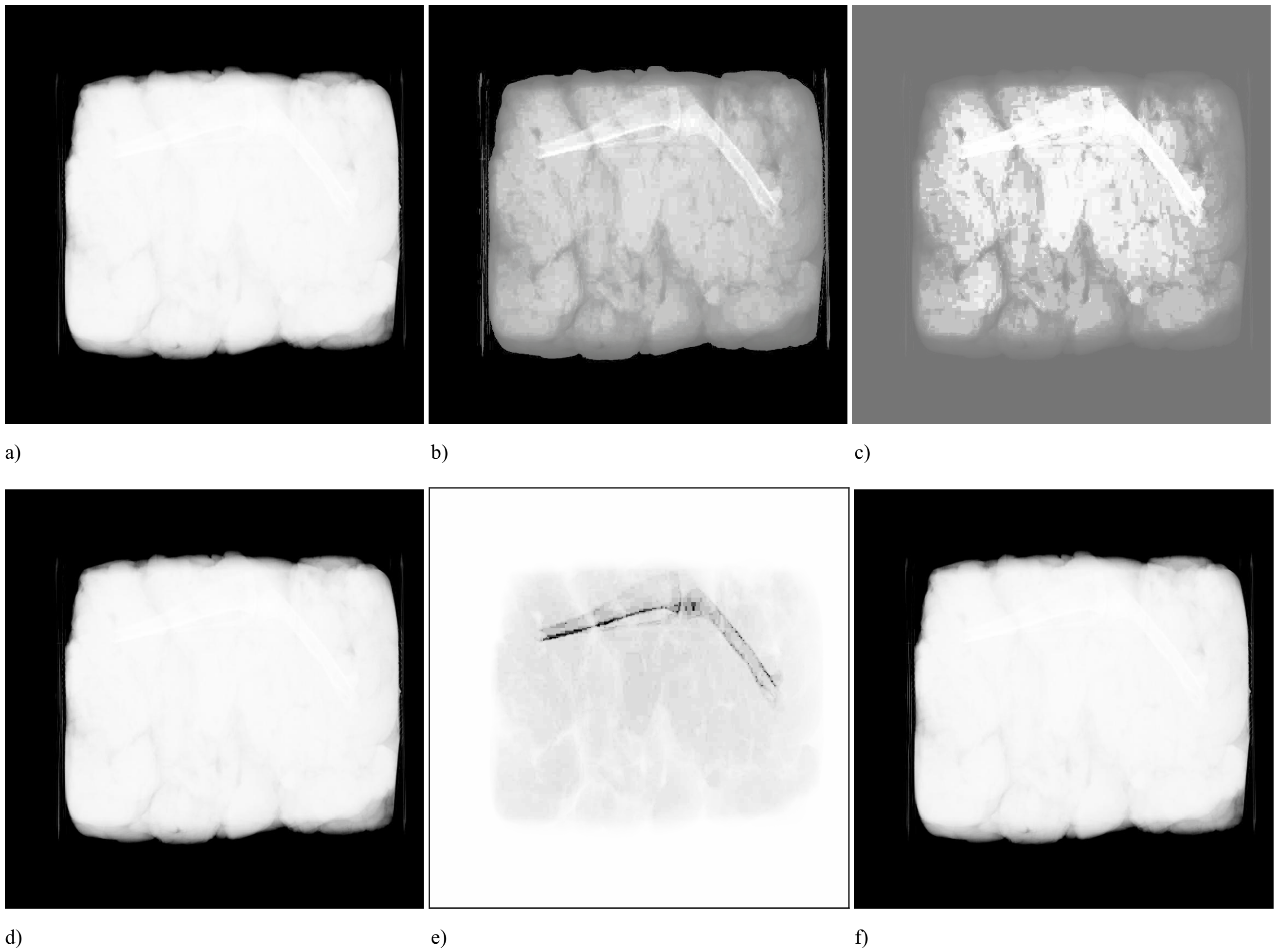



**Fig. 2. The enhancement results for test image *Meat*, a) original image, b) output of the proposed approach, c) output of histogram equalisation, d) output of linear stretching, e) output of contrast reverser, f) output of modified linear stretching.**

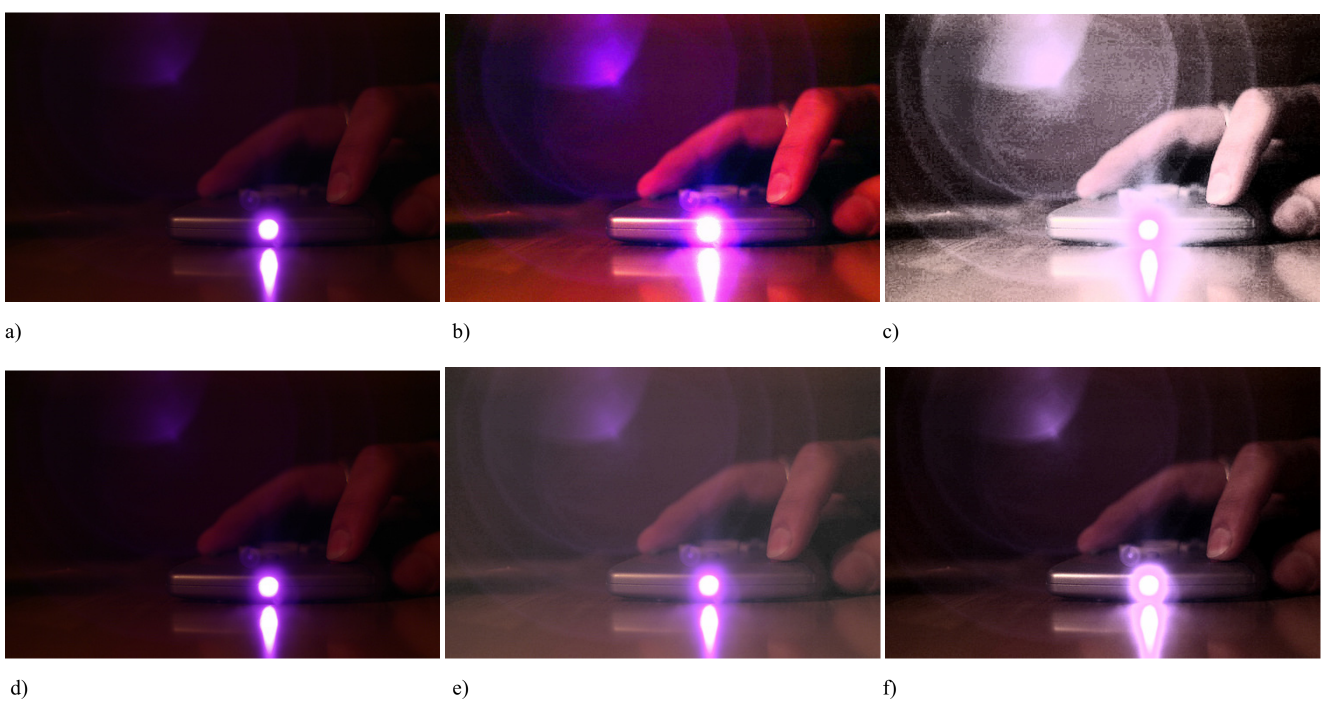



**Fig. 3. The enhancement results for test image *Light*, a) original image, b) output of the proposed approach, c) output of histogram equalisation, d) output of linear stretching, e) output of gamma correction, f) output of GC-CHE.**

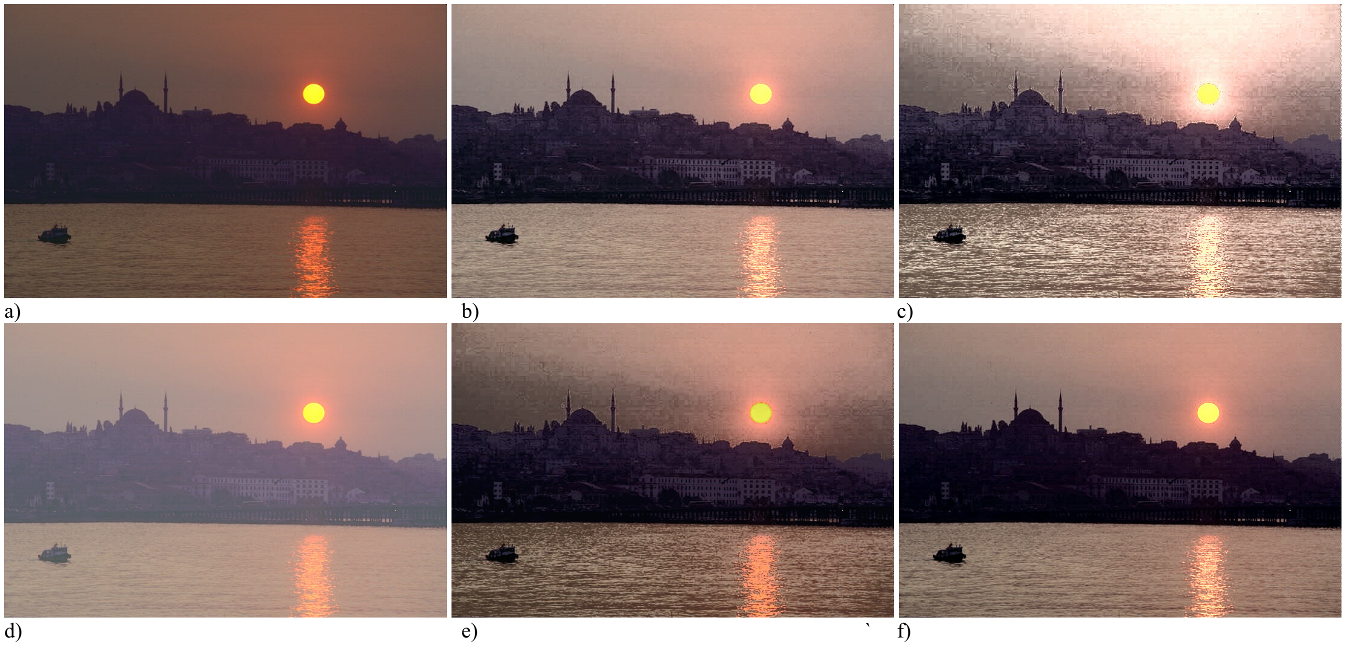



**Fig. 4. The enhancement results for test image *Scene*, a) original image, b) output of the proposed approach, c) output of histogram equalisation, d) output of gamma correction, e) output of PBDHE, f) output of DRSHE.**

Contrast reverse transfer function [2] and gamma correction [2, 4] are often helpful in visualizing details in dark areas of an image. Therefore, the results of the reverse function and gamma correction are used in the experiments for comparison (see Fig.2e, Fig.3e and Fig.4d). The reverse function, which was clipped at 10% input amplitude levels to maintain the output amplitude within the range of unity, was applied to the inverted original image, and then the resultant image was reverted after the enhancement process. The modified contrast stretch was obtained by truncated input scale range at both the low and the high ends, corresponding to the 1% histogram distribution.

## IV. CONCLUSION

In this paper, a new hybrid approach based on a virtual histogram modification for colour image enhancement is proposed. The novelty of the proposed method is that colour image enhancement is based on modification of a virtual histogram distribution, which is a new way to integrate colour and brightness information extracted from salient local features, for global contrast enhancement. The special contributions 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 aspects of the image. If the parameters are set up to default values, the proposed method will work as an automatic process. The proposed approach has a potential for various applications to enhance specific categories of images, such as surveillance videos/images, biomedical images and satellite images.

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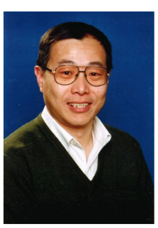

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