Contrast Enhancement for Emissive Display Using Histogram Equalization and Bilateral Tone Adjustment

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***Abstract* -** Contrast enhancement has an important role in image processing applications. Conventional contrast enhancement techniques often fail to produce satisfactory results for broad variety of low contrast images or cannot be automatically applied to different images, because their parameters must be specified manually to produce a satisfactory result for a given image. A Power Constrained Contrast Enhancement algorithm for emissive displays based on histogram equalization (HE) and Bilateral Tone Adjustment Technique is proposed in this paper. For PCCE algorithm a log based histogram modification scheme which reduces the overstretching artifacts of the conventional HE technique is proposed. Then a power-consumption model for emissive displays was developed and an objective function consisting of histogram equalizing term and the power term was formulated. By minimizing the objective function based on the convex optimization theory its found that the proposed algorithm achieves contrast enhancement and power saving simultaneously. Then the bilateral tone adjustment technique is used to improve the image quality. BiTA is applied to the luminance, while the color saliency detector calculates the amount of saliency of each pixel with respect to neighbourhood. Saliency produces a saliency map with well defined boundary of salient object. Regions with higher saliency values indicate that the regions have a higher extent of human interest deserve a greater degree of enhancement. Saliency Weighted Contrast Enhancement is then performed based on the adjusted luminance and saliency. The Simulation results demonstrate that the Bilateral Tone Adjustment Technique can reduce power consumption significantly while improving image contrast and perceptual quality.

***Keywords* -** image/video quality enhancement, emissive display, histogram equalization(HE), histogram modification(HM), Power saving, probability density function, saliency.

I.INTRODUCTION

Images are captured at low contrast in a number of different scenarios. The main reason for this problem is poor lighting conditions (e.g., pictures taken at night or against the sun rays). As a result, the image is too dark or too bright, and is inappropriate for visual inspection or simple observation. The most common way to improve the contrast of an image is to modify its pixel value distribution.

Contrast enhancement is frequently referred as one of the most important issues in image processing. Contrast is created by the difference in luminance reflected from two adjacent surfaces. In visual perception, contrast image enhancement is the process of enhancing the visual information within the image. The goal of digital image enhancement is to produce a processed image that is suitable for certain application.

There are two distinct strategies to achieve this goal. First, the image can be displayed appropriately so that the conveyed information is maximized. Second, the image can be processed so that the informative part of the data is retained and the rest discarded.

Our visual system is more sensitive to contrast than absolute luminance. If the contrast of an image is highly concentrated on a specific range, the information may be lost in those areas which are excessively concentrated. The problem is to optimize the contrast of an image in order to represent all the information in the input image. Several contrast enhancement techniques have been introduced to improve the contrast of an image. These techniques can be broadly categorized into two groups: direct methods and indirect methods.

Direct methods define a contrast measure and try to improve it. Indirect methods, on the other hand, improve the contrast through exploiting the underutilized regions of the dynamic range without defining a specific contrast term. Most methods in the literature fall into the second group. Indirect methods can further be divided into several subgroups:
i) techniques that decompose an image into high and low frequency signals for manipulation, e.g., homomorphic filtering

ii) histogram modification techniques and
iii) transform-based techniques.

In addition to contrast enhancement, power saving is also an important issue in various multimedia devices, such as mobile phones and televisions. A large portion of power is consumed by display panels in these devices and this trend is expected to continue as display sizes are getting larger.

The paper is organized as follows. Section II provides an overview of image histogram, HE and HM. Section III proposes the LHM. The Power consumption model is provided in Section IV. Bilateral Tone Adjustment (BiTA) and Saliency Weighted Contrast Enhancement (SWCE)technique is provided in Section V. Section VI gives the results and discussions. Conclusion is given in section VII.

II.METHODOLOGY

A PCCE algorithm is proposed for emissive displays based on HE,

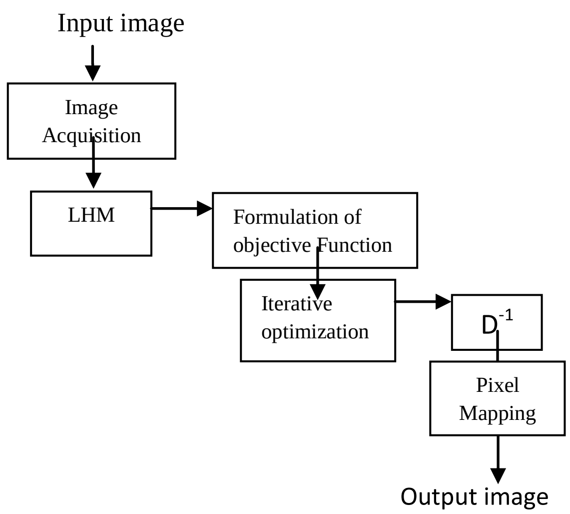

Fig1.Flow diagram for PCCE Algorithm

The flow diagram PCCE algorithm is shown in Fig.1. The histogram information from an input image are gathered and apply the LHM scheme to obtain the modified histogram m**.** Then an objective function, which consists of power term and HE terms is designed. In order to reduce power consumption the objective function is reduced by finding the optimal y that minimizes the objective function through iterative optimization. Finally, the transformation function x is constructed from **y** via x = D ˉ1*y* and use x to transform the input image to the output image.

II. A. IMAGE HISTOGRAM

An image histogram is a graphical representation of a digital image. It plots the number of pixel for each tonal value. The horizontal axis of the graph represents the tonal variations, while the vertical axis represents the number of pixels in that particular tone. The left side of the horizontal axis represents the black and dark areas, the middle represents medium grey and the right hand side represents light and pure white areas. The vertical axis represents the size of the area that is captured in each one of these zones. Thus, the histogram for a very dark image will have the majority of its data points on the left side and center of the graph.

B. HISTOGRAM EQUALIZATION

Histogram equalization is a method in image processing of contrast adjustment using the image's histogram.For a given image X, the probability density function p(Xk) is defined as

$$P(X_k)=n^k/n$$

For $k = 0, 1, \ldots, L - 1$, where n^k represents the number of times that the level *Xk* appears in the input image X and n is the total number of samples in the input image. p(Xk) is associated with the histogram of the input image which represents the number of pixels that have a specific intensity Xk. In fact, a plot of nk vs Xk is known as histogram of X. Based on the probability density function, the cumulative density function is defined as

$$c(x) = \sum_{j=0}^{k} p(X_j)$$

y

where $Xk = x$, for $k = 0, 1, \ldots, L - 1$. HE is a scheme that maps the input image into the entire dynamic range, $(X0, XL\text{-}1)$ by using the cumulative density function as a transform function. Let's define a transform function $f(x)$ based on the cumulative density function as

$$f(x)=X_0+(X_{L-1}-X0)c(x)$$

The high performance of the HE in enhancing the contrast of an image as a consequence of the dynamic range expansion Besides, HE also flattens a histogram. HE can introduce a significant change in brightness of an image, which hesitates the direct application of HE scheme in consumer electronics.

III.LOG BASED HISTOGRAM MODIFICATION

This transformation is used to expand the values of darker pixel in an image while compressing higher level values. Histogram modification (HM) technique that employs histogram information in an input image to obtain the transformation function x.

HM scheme is developed using a logarithmic function, which is monotonically increasing and reduce larger value to preserve the details.

The logarithm function to convert the input histogram value h_k to a modified histogram value m_k is as follows,

$$m_k=\log(h_k.h_{max}.10^{-\mu}+1)/\log(h_{max}^2.10^{-\mu}+1)$$

h_{max} is maximum element within the input histogram

μ is the parameter to control the level of histogram modification.

IV.PCCE

A. *Formulation of Objective Functions*

The core is to reduce total dissipated power. The objective function consisting of the histogram-equalizing term and the power term. The pixel value is altered to save power in the display panel. The objective function is expressed in terms of variable y = Dx. The total dissipated power in terms of contrast enhanced and histogram values are as follows,

$$TDP=h^t\phi^\gamma(x)$$

Where $\phi^\gamma(x)=[x0^\gamma,x_1^\gamma,\ldots,x_{L-1}^\gamma]^t$

h is the histogram vector whose kth element is h_k

γ is any number greater than or equal to 1.

The optimization problem consists of maximizing and minimizing the real function by systematically choosing input values from within an allowed set and computing the value of the function. The sustain power is proportional to the average picture level which is the average of luminous intensities of all pixels in an image. The average picture level is, in turn, linearly proportional to the TDP in since it is obtained by dividing the TDP by the number of pixels TV.

B. *Iterative Optimization*

The constrained optimization problem is to maintain minimum and maximum intensity. When Dx≥0,x should be monotonic. The problem is said to be constrained because conditions are imposed on the independent variables x and assume that f is defined for all y. This methods can fail if the objective function has discontinuities or irregularities.

In order to reduce power declare a variable y and input initial value to y_k from x. x is a transformation function which is obtained from histogram modification scheme using Dx=m. y_k is the new variable in y. y is the difference between two output pixel intensity.

$$D=\begin{bmatrix}1 & 0 & \cdots & 0 & 0\\ \vdots & & \ddots & & \vdots\\ 1 & 1 & \cdots & 1 & 1\end{bmatrix}$$

Using y=Dx ,find the positive value of y_k and neglect other

all,

$$y_{i+1} = y_i+ \overline{m}_{i+1}- \overline{m}_i+ \alpha\gamma/2\ h_i\left(\sum_{k=1}^{i} y_k\right)^{\gamma-1}$$

Find the z value using Secant formula in order to compute all the values of y_i. y_i values is expressed using a single variable z. The value of i is in between 1 and L-2,where L is intensity level which is 256 for 8 bit image. y_i is the monotonically increasing function of z, since $y_i=g_i(z)$.

$$z^{(n)}= z^{(n-1)} - \frac{z^{(n-1)}-z^{(n-2)}}{f(z^{(n-1)}) - f(z^{(n-2)})} f(z^{(n-1)})$$

Here $f(z^{(n-1)})$ and $f(z^{(n-2)})$ are f(z) terms on n-1 and n-2 iteration. n is a variable which tells the number of iteration to perform in order to compute the unique solution to f(z)=0. f(z) is monotonically increasing function of z.

$$f(z)=\sum_{i=1}^{L-1} g(z)-(L-1)$$

The value of n starts from 2,3…The value of y_i changes on each iteration based on the z value. Find for which n value the f(z) become zero using y_i value determined on each iteration based on histogram modification value.

To avoid unbalance between power and histogram equalizing term, the parameter α is controlled. To compute the values of y_i ,take gamma value as 2.2 and alpha from below equation

$$\beta=\alpha*\sum_{i=0}^{N-1} Y_{input,i}$$

Bright image can be improved with γ>1 and darker image benefits from using γ<1.As β gets larger the value of y_i increases for high pixel value and decreases for low pixel value. These changes in y_i reduces the power consumption with improved image quality.

V. BILATERAL TONE ADJUSTMENT (BITA)

To adjust brightness RGB cannot be used because each of the three color channels would get changed and changing them by the same amount to adjust brightness will usually shift the color. So the input RGB image is transformed into the HSV domain to derive the luminance and color maps. Hue is the quantity that distinguishes color family. Saturation is color intensity or degree of color sensation from that of white or gray. Value is the brightness of pixel. HSV is obtained by mathematically transforming RGB.

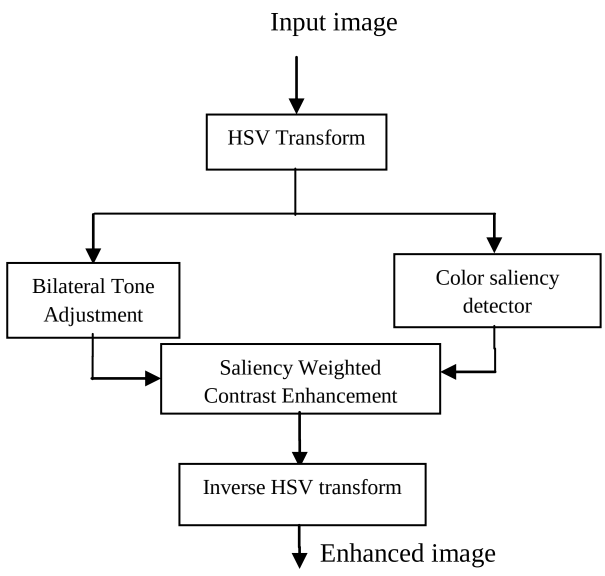

Fig 2. Flow diagram for BiTA/SWCE

Then, BiTA is applied to the luminance while the color saliency detector calculates the amount of saliency of each pixel with respect to neighbourhood. Saliency produces a saliency map with well defined boundary of salient object. Regions with higher saliency values which indicate that the regions have a higher extent of human interest, deserve a greater degree of enhancement. Saliency Weighted Contrast Enhancement is then performed based on the adjusted luminance and saliency. Finally, the output image is the inverse HSV transform of the enhanced luminance map with the original color maps.

V.A)*HSV Transform*

To adjust brightness RGB cannot be used, Because each of the three color channels would get changed and changing them by the same amount to adjust brightness will usually shift the color. RGB values will vary a lot depending on strong or dim lighting condition. It is not more accurate to measure small color difference. So In order to measure the color difference properly, RGB color image is converted into HSV color spaces.

The HSV describe the color relationship more accurately than RGB, so it attempts to characterize colors according to their hue, saturation, and value (brightness).

B)*Bilateral Gamma Adjustment*

The bilateral gamma adjustment (BiGA) is used to adjust the global luminance using the gamma adjustment function by taking value as its input. Global luminance is to reassign the intensity values of pixels to make the intensity distribution uniform. This method improves the visibility of details in dark and bright region.

$$G_a(L)=(G_d+G_b)/2$$

G_a is the gamma adjustment factor which enhance the contrast in bright and dark region. G_d and G_b are the function for enhancing dark and bright region.

$$G_d(L)=L^{1/\gamma}$$
$$G_b(L)=1-(1-L)^{1/\gamma}$$

Where L is the input luminance and γ is the user specified variable that indicate the degree of enhancement. Gamma correction allows users to adjust the lightness or darkness level. The enhancement is not obvious when γ is too small. But when γ is very large, the enhancement in dark and bright regions would be prominent while the details in mid-tone region would be almost disappeared. The amount of correction is specified by a single value ranging from 0.0 to 10.0.

C) *Colour Saliency Detector*

Colour saliency detector produces the saliency map by taking hue and saturation as input with well defined boundary of salient object. The main objective of salient region detection is used to compute degree of saliency of each pixel with respect to neighbourhood value in terms of its color and lightness properties. Saliency is the quality of the item that stands out related to neighbouring items.

Regions with higher saliency values deserve a greater degree of enhancement. The brightness of the image is proportional to saliency. To segment a salient object, it is necessary to binarize the saliency map such that ones (white pixels) correspond to salient object pixels while zeros (black pixels) correspond to the background.

The saliency map S for an image I with width W and a height H is given as follows,

$$S(x,y)=[I\mu-I_{whc}(x,y)]$$

$I\mu$=arithmetic mean pixel value of the image

$I_{whc}(x,y)$= image pixel vector value of original image.

The fixed threshold value is used to binarize the saliency map.

D) *Saliency Weighted Contrast Enhancement (SWCE)*

To strengthen local contrast enhancement, Saliency Weighted Contrast Enhancement (SWCE) is performed after BiTA. In BiTA, Global contrast enhancement is performed. Saliency Weighted Contrast Enhancement (SWCE) balances the global luminance (value) and saliency map which reveal the details and produces much less artifacts. SWCE is designed to produce high contrast in region with higher extent to human interest. In addition, the noise is not over enhanced because SWCE controls the enhancement extent adaptively depending on local saliency values. If local pixel mapping functions are obtained from the neighborhood around each pixel, it is a local method. Local methods may provide stronger enhancement effects than global methods.

A simple approach to enhance contrast is shown below,

$$\hat{L}_x = \overline{L_x} + \beta sal_x(\overline{L_x} - m_x)$$

Where β=enhancement factor

sal_x= saliency value of pixel x

m_x=local mean of pixel x

$\overline{L_x}$ = luminance value of pixel x processed by BiTA

$\hat{L}_x$ = enhanced luminance of pixel x

As a result, pixels with higher saliency values derive more contrast gain, and pixels with zero saliency values are ignored. To maintain the color the value is alone modified in SWCE image. It is converted to RGB image by taking inverse HSV Transform.

PARAMETER CALCULATION

A) *Contrast-Per-Pixel*

Contrast-per-pixel measures the average intensity difference between a pixel and its adjacent pixels whose intensities are less than that of the current pixel. This value shows the local contrast of the image. If an image is N pixels by M pixels in size then the average contrast is given as,

$$C = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}\left(\sum_{(m,n)\in Rm^{(i,j)}} |\gamma(i,j)-\gamma(m,n)|\right)}{M*N}$$

B) *Mean Brightness Error*

In order to determine MBE, the input image should be partitioned into a number of regions by detected peak point. Each region is independently expanded for full dynamic histogram range. In order to minimize the MBE, the roughly detected peak point will be finely adjusted by shifting them in a certain defined range. The MBE gradually reduces when the separation is increased. The difference occurs because of randomness .

$$\text{MBE}=\frac{1}{S}\sum_{n=1}^{S}|\tilde{X}-\tilde{Y}|$$

where S is the total number of sample images, $\tilde{X}$ and $\tilde{Y}$ are the average intensity of the original and resultant images respectively.

C) *Histogram Flatness*

Histograms are made up of bins, each bin represents a certain intensity value range. The histogram is computed by examining all pixels in the image and assigning each to a different intensity levels or 'bins' depending on the pixel intensity. It displays the number of pixels in an image for a particular intensity level. The large bins can be avoided by adding a small amount of uniform noise to each pixel's intensity value prior to equalization. The flatness of a histogram *h* is measured using the formula,

$$\sigma = \frac{\sum_{0}^{D-1}(|h_i|-\mu_h)^2}{D}$$

Where $|h_i|$ is the size of the i-th bin of the image histogram

μ_h is the mean histogram of the bin size

D is the image intensities

VI. RESULT AND DISCUSSION

A) *Results Of PCCE*

The PCCE algorithm is applied to still image and it improve the contrast of the image with reduced power consumption is shown as follows.

Fig. 3 Input still image

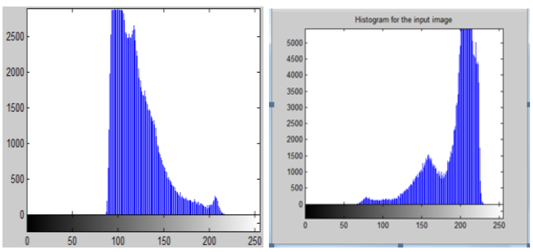

Fig. 4 Histogram for the input image

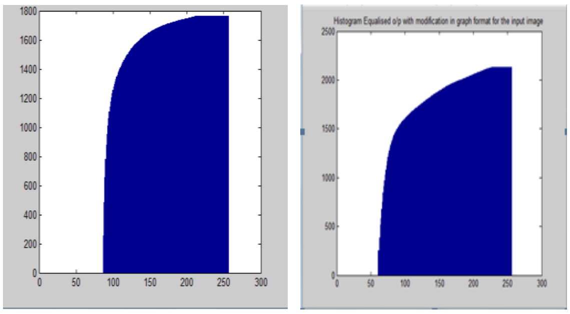

Fig. 5 Histogram equalized output with modification in graph format

Fig. 6 Contrast improved final image

B)*Results Of BiTA*

The input image taken is RGB image.

Fig.7 Input Images

The saliency map is obtained by taking hue and saturation as input image using color saliency detector.

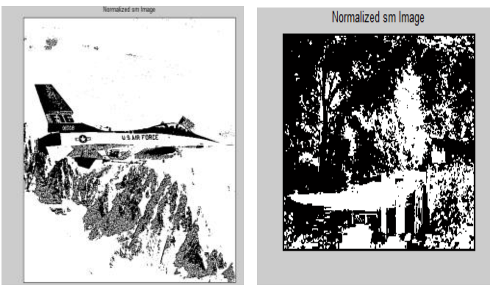

Fig.8 Saliency Map

The enhanced global luminance image shown is obtained by taking value as input using Bilateral Gamma Adjustment.

Fig.9 Enhanced Global Luminance (Value) of BiGA

Saliency Weighted Contrast Enhancement (SWCE) perform local contrast enhancement after BiTA. Saliency Weighted Contrast Enhancement (SWCE) balances the enhanced global luminance (value) and saliency map which produces much less artifacts.

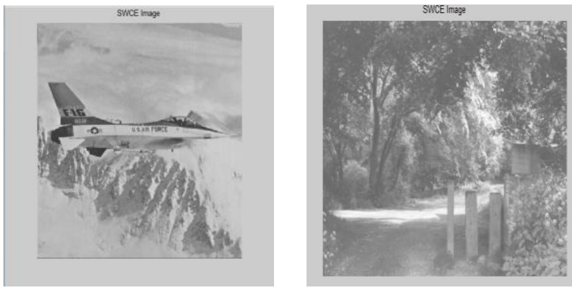

Fig.10 SWCE Image

- To maintain the color, the value alone get modified in SWCE image. It is then converted to RGB image.

Fig.11 Enhanced RGB Image

COMPARISON RESULT FOR POWER CONSTRAINTS

TECHNIQUE	AIRPLANE	SCENARY
PCCE	5.0264e+009	4.7359e+009
BiTA	5.7751e+009	4.9486e+009

Table. 1 Comparison table for Power Constraint using both techniques

COMPARISION RESULT FOR PARAMETERS CALCULATION

PARAMETERS	AIRPLANE	SCENARY
CONTRAST PER PIXEL	8.0872	6.6974
MBE	167.53	62.5118
HISTOGRAM FLATNESS	81.169×10^3	45.514×10^3

Table.2 Comparison table for Parameter Calculation using PCCE Algorithm

PARAMETERS	AIRPLANE	SCENARY
CONTRAST PER PIXEL	13.7147	6.7272
MBE	94.2265	38.0680
HISTOGRAM FLATNESS	81.145×10^3	45.5×10^3

Table.3 Comparison table for Parameter Calculation using BiTA techniques

VII.CONCLUSION

In BiTA technique, contrast per pixel value is increased while the histogram flatness and mean brightness error values are reduced simultaneously comparing to PCCE algorithm. BiTA technique maintains its power reduction obtained from PCCE algorithm with improved image quality than PCCE Algorithm. Hence BiTA technique produces better contrast enhancement results comparing to PCCE Algorithm.

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