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MEDIAN AND KURTOSIS BASED BI-HISTOGRAM EQUALIZATION FOR IMAGE ENHANCEMENT

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ABSTRACT

In the present paper, kurtosis and median based bi-histogram equalization algorithm has been suggested for contrast enhancement of images under poor light condition. Histogram clipping threshold value is computed through the kurtosis on an image histogram to control the over enhancement rate. After histogram clipping process, it is separated into two sections, through histogram subdivision limitation constraint founded on the median value of the histogram. Histogram of particular sub-image is equalized autonomously and then integrated into one output enhanced image. The output image is further processed for more improvements and transformed into HSV colour space to have the saturation value of the colour channel and some modification is done. The HSV image is converted back to RGB colour as a final enhanced image. The quantitative evaluation has shown that the proposed kurtosis and median based bi-histogram equalization algorithm produce a superior quality of image in comparison to the other image enhancement algorithm in terms of image quality metric FSIM. Therefore, proposed image enhancement algorithm warrants more investigation.

KEYWORDS

Image Enhancement, Histogram Equalization, Clipping Threshold, Median, Kurtosis.

1. INTRODUCTION

Digital image processing deal with image segmentation, restoration, morphological operation, enhancement of image and equalization of histogram (Gonzalez and Woods, 2007). The histogram equalization is a well-known algorithm for contrast enhancement of image. Chen et al proposed minimum mean brightness error bi-histogram equalization (MMBEBHE) algorithm (Chen and Ramli, 2003). MMBEBHE is an improved version of BBHE algorithm. Singh et al. suggested exposure based sub-image histogram equalization (ESIHE) algorithm for low light gray scale image contrast enhancement (Singh et al., 2014a). Recursive HE algorithm (RESIHE) is introduced by Singh et al. for poor light exposure image enhancement (Singh et al., 2015). Singh et al. recommended median mean-based sub-image clipped HE (MMSICHE) method, where an image histogram was partitioned into four sub histograms (Singh et al., 2014b). Images found from MMSICHE algorithm produce poor contrast images with artifacts. Tuned Tri-threshold fuzzy intensification operators (TTFIO) algorithm usages a fuzzy membership function to produce better colour. Multiscale Retinex method is applied for image enhancement based on Gaussian scales, offset and gain, etc (Al-Ameen, 2016). An advanced Retinex algorithm founded on PSO algorithm is utilized to tune multiscale Retinex with chromaticity preservation (MSRCP) for image enhancement (Jobson et al., 1997). Jobson et al. suggested single-scale Retinex (SSR), and Multiscale Retinex with colour (MSRCR) founded on Land's Retinex (Liu et al., 2018). SSR is a center bounded algorithm, and the lighting is measured via the variance among the input value of the pixel gray or colour level at the center and an average of its neighbourhood.

1.1 Contributions of the suggested method

In the proposed algorithm the histogram clipping threshold is computed by the kurtosis to control the over enhancement of the image. Histogram separation is done by the median value. The histogram is subdivided into two section using sub histogram, which is founded on the median value of the image. In the proposed technique, two sub-histograms have been found, and they have been successively united to attain a single continuous histogram. The pixel value which is greater than the clipping threshold value is removed. Probability density function (PDF) and cumulative distribution function (CDF) are calculated on the sub images. Transfer function is applied for histogram equalization and finally both sub-images is integrated into one final image. Then the output enhanced image is further processed for more improvement. RGB colour space is converted to HSV colour space. Some adjustment is done on saturation and value channel by multiplying saturation and value channel by a small value of alpha, which is a tunable parameter which is between 0.5 to 1.5. Processed HSV image is converted to RGB colour space. Performance evaluation is done through the image quality metrics such as FSIM (Zhang et al., 2011).

2. PROPOSED METHODOLOGY

2.1 Total image pixel computation

$$T_p = \sum_{ik=0}^{L-1} H(ik)$$

(1)

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Here, T_p is a total image pixel. L is the maximum intensity level and $H(ik)$ denotes image histogram.

2.2 Mean calculation is shown in (2)

$$M_\psi = \frac{\sum_{ik=0}^{L-1} ik \times H(ik)}{\sum_{ik=0}^{L-1} H(ik)} \quad (2)$$

M_ψ is a mean of ik .

2.3 Standard deviation

$$S_d = \sqrt{\frac{\sum_{ik=0}^{L-1} (ik - M_\psi)^2 \times H(ik)}{\sum_{ik=0}^{L-1} H(ik)}} \quad (3)$$

S_d is a standard deviation of ik .

2.4 Median

$$M_n = \left\{ \frac{H(ik)}{2} \right\} \quad (4)$$

M_n is a median of ik .

2.5 The kurtosis is the kurtosis

$$T_s = \frac{(M_\psi)^4}{(S_d)^4} \quad (5)$$

T_s is clipping threshold computed through kurtosis.

2.6 Kurtosis-based Histogram clipping

The clipping of histogram is a method to restrict the rate of over enhancement effect to keep the image natural appearance. The histogram bins those have a higher value compare to the clipping threshold value are removed. The clipping threshold is computed by the kurtosis on the histogram.

$$H_c(ik) = \begin{cases} T_s & \text{if } H(ik) \geq T_s \\ H(ik) & \text{if } H(ik) < T_s \end{cases} \quad (6)$$

$H(ik)$ and $H_c(ik)$ are the original and clipped histogram.

2.7 Median based Histogram Subdivision

The processed histogram is equally segmented into two section founded on median value X_m as computed in (4). The histogram subdivision process returns two sub-images X_l and X_u which range from intensity level 0 to X_m and $X_m + 1$ to $L-1$. L is 255, maximum intensity level in image.

2.8 Probability density function (PDF)

$P_l(ik)$ and $P_u(ik)$ are corresponding PDF of the sub images as defined below:

$$P_l(ik) = H(ik) / S_l \text{ for } 0 < ik < X_m \quad (7)$$

$$P_u(ik) = H(ik) / S_u \text{ for } X_m + 1 < ik < L-1 \quad (8)$$

Where S_l and S_u are a total number of pixels in sub-images $P_l(ik)$ and $P_u(ik)$ respectively.

2.9 Cumulative density function (CDF)

CDF of individual sub-images are defined as

$$C_l(ik) = \sum_{ik=0}^{X_p} P_l(ik) \quad (9)$$

$$C_u(ik) = \sum_{ik=X_{p+1}}^{L-1} P_u(ik)$$

The following step of the proposed algorithm is to equalize both the sub histograms separately. The transfer function for histogram equalization are defined through equation (11) and (12) can be defined as

$$T_l = X_m \times C_l \quad (11)$$

$$T_u = (X_m + 1) + (L - X_m + 1) C_u \quad (12)$$

The individual sub histograms equalization is implemented through the transfer function T_l and T_u . After then, integration of both sub-images is done to produce one final image. Then this final image is further processed by converting the image to HSV image for colour improvement. The

saturation and value channel of the image is multiplied by a small value of alpha between a value 0.5 to 1.5. Then the processed HSV image is converted back into RGB image as a final enhanced image.

Matlab simulation was done on BSD (Berkeley Segmentation Database) images (MATLAB, 2018a; Arbelaez et al., 2011). All the algorithms are implemented on Windows 10 operating system through Intel core i7 central processing unit (CPU) at 2.30 GHz and 8 gigabytes (GB) random access memory. Visual quality inspection and performance measurement are done on the output images.

3. PROPOSED ALGORITHM

Kurtosis and median based histogram equalization method has been proposed for contrast enhancement of digital images.

- **Histogram clipping is done** with the help of threshold limit calculated from kurtosis.
- **Histogram is partitioned** into two section by histogram limit parameter X_m , which is computed based on the median value.
- **The enhance image** is converted to HSV colour model for colour improvement by standard conversion formula and in this way, image components like hue, saturation and value (HSV) are separated. Fine-tuning is done by multiplying the saturation and value channel by a pre-defined value of alpha, a tunability factor. It finds the modulus value of the hue of the image and ultimately the process stops if the value becomes greater than 1. Then the values of saturation, value (intensity) and modulus hue value are combined to get a modified form of HSV image. This is re-converted into RGB model for better visualization of the resultant image.

4. Quantitative Evaluation

Quantitative evaluation is done to measure visual quality over the publicly available BSD image dataset [11]. Performance evaluation is done through various image quality metrics such as FSIM [9].

4.1 Feature similarity index metric (FSIM)

Zhang proposed Feature similarity index metric (FSIM) [9] metric to measure image quality, shown in equation 13. FSIM demonstrates the complete similarity among the input image and the output image. The original and enhanced image are signified by f_1 and f_2 , correspondingly. Phase congruency (PC) for $f_1(y)$ and $f_2(y)$ are signified as PC_1 and PC_2 , correspondingly. $S_L(y)$ designates local similarity of $f_1(y)$ and $f_2(y)$ at pixel location y . $PC_m(y)$ is computed as the maximum of $PC_1(y)$ and $PC_2(y)$. FSIM among images f_1 and f_2 is expressed as

$$FSIM = \frac{\sum_{y \in \Omega} S_L(y) \cdot PC_m(y)}{\sum_{y \in \Omega} PC_m(y)} \quad (13)$$

The entire image in the spatial domain is allocate by Ω . Table 1 demonstrates FSIM values, and it is detected that the proposed algorithm generates the highest FSIM values for all images besides '15011' image of BSD database. The proposed method gives average FSIM value 0.88356, shown in bold face which demonstrates the best outcome with compared to the other methods. The next best average FSIM result is given by TTFIO algorithm which gives average FSIM value as 0.87418, is designated by underline

(a) Original Image

Figure 1: (a) Original image (c) Original histogram (b) proposed method image (d) Proposed method histograms.

5. SIMULATION RESULTS AND ANALYSIS

5.1 Visual quality assessment

Figure 2: Original image of the 'Flight' and the outputs of various contrast enhancement algorithms.

Table 1 : FSIM								
Original BSD Image	RESIHE	ESIHE	SSR	MSRCR	MSRCP	TTFIO	MMSICHE	Proposed
"14085"	0.47417	0.48292	0.70421	0.71827	0.39921	0.89722	0.47396	0.89908
"14092"	0.47902	0.48919	0.75354	0.75828	0.41471	0.88603	0.51053	0.88609
"15011"	0.54614	0.55105	0.69421	0.70759	0.45795	0.87298	0.54972	0.87257
"16004"	0.58174	0.58962	0.77289	0.81665	0.45554	0.86614	0.59016	0.86998
"3063"	0.71564	0.72114	0.89929	0.89062	0.69392	0.91519	0.71539	0.91497
"5096"	0.47402	0.48811	0.49582	0.51569	0.33106	0.84717	0.50324	0.90440
"6046"	0.43616	0.44519	0.62145	0.63788	0.3789	0.83453	0.46246	0.83787
Average	0.52955	0.53817	0.70591	0.72071	0.44732	0.87418	0.54363	0.88356

Fig. 2 displays the original image '361010' of the 'Flight' and the results of different images obtain by different enhancement algorithm. ESIHE algorithm gives little contrast enhance the image. MMSICHE algorithm shows little brighter image than ESIHE, but with less contrast. R-ESIHE algorithm produces better contrast enhancement of image than ESIHE and MMSICHE algorithm. TTFIO algorithm formed an image with over contrast which makes image darker. SSR algorithm illustrates an over brighter image. MSRCR displays almost the same result as SSR but produced an image with slightly better color. But the overall performance of SSR and MSRCR algorithm gives the poor quality of visual result. The overall performance of the proposed algorithm is superior to related algorithm.

The proposed algorithm formed an image with natural vibrant color, contrast, and brightness.

6. CONCLUSION

Present paper offers a new method for image contrast enhancement via kurtosis and median based histogram equalization method for Bi-histogram subdivision and equalization of image for low contrast image enhancement. The rate of over enhancement of the image is controlled by using the histogram clipping. The present method maintained the contrasts and colours of image and improved the prominence of the low-

light effects on image regions. Matlab simulation results demonstrates the proposed algorithm gives better figure merits that outperform than other algorithm in terms of FSIM the proposed algorithm may be improved by processing the histogram through other statistical methods for both histogram partitioning and equalization of the sub-image histograms for more improved and natural image enhancement.

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