CONTRAST ENHANCEMENT USING NON-SUBSAMPLED CONTOURLET TRANSFORM WITH HISTOGRAM EQUALIZATION FOR ULTRASOUND IMAGES

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Abstract--Enhancement of contrast in an image is a vital process of image processing, it increases the intensity of image pixels. By enhancing the contrast of an image, the quality of the image will be increased. The anticipated technique is the combination of non-subsampled contourlet transform and bilateral filter. The key contribution of this paper is the usage of a weighted mean separated sub-histogram equalization technique for increasing the contrast of medical ultrasound images. The performance of the proposed technique provides improved contrast enhancement features when related with the existing methods such as contourlet transform and Histogram Equalization in terms of structural similarity index matrix, PSNR and Absolute Mean Brightness Error.

KeyWords: Bilateral filter, weighted mean separated sub-histogram equalization, non-subsampled contourlet transform, ultrasound image.

1. INTRODUCTION

Extracting data from the Medical ultrasound images need high quality images. The quality of an image is one of the major problems on information extraction with image. The contrast of image is an important factor on the quality of image. for increasing the contrast of image various techniques are designed in [2]. There also have a set of techniques on transform domain for enhancing the contrast, such as wavelet, curvelets, and contourlet transform [3][10]. These techniques calculate the coefficients for the input image and it is modified by using the mapping functions, after that it will be rebuild to obtain the enhanced image [4]. Histogram Equalization (HE) improves the contrast of numerous images, particularly while the functional information of the medical image is characterized by nearby contrast values [5-6]. The intensities of the histogram will be allocated with this adjustment. It makes to increase the contrast of pixel area available on the image with lower contrast. The main problem occurs in the transform-based technique such as contourlet transform is shift-variant. The presence of down-samplers and up-samplers in the Laplacian pyramid and the directional filter bank in contourlet transform [12], the transform is not shift-invariant. By using the transform-based technique, there is possibility to loss some symmetrical information of image. This issue will be resolved by using the Non-subsampled Contourlet Transform (NSCT) [7]. NSCT can deliver the smooth appearance of contours of image. One of the techniques of nonlinear filtering is Bilateral filtering presented by Tomasi et al. [1]. It introduces the concept of smoothing by weighting the filter coefficient with their
component intensities. Spatial distance and the intensity distance depend upon weights of the pixels in local neighborhood. The proposed technique initially decomposes the input image by applying NSCT and generates several coefficients. These coefficients are filtered with Bilateral filter. Finally, Weighting Mean-Separated Sub-Histogram Equalization (WMSHE) is used to enhance the image contrast.

The rest of the work is organized as: section II describes the proposed method. Section III indicates the performance metrics. Section IV illustrates results and discussions. Section V includes conclusion and references.

2. PROPOSED METHOD

In our proposed system, initially on source image we are applying the Non sub-sampled Contourlet Transform (NSCT) for decomposing the image. While decomposing the image at different scales, the image can be decomposed into a set of contourlet coefficients with different spectral resolution having numerous sub bands. A non-linear Bilateral Filter (BF) is performed on different contourlet coefficients to smooth the edges. After this process, inverse NSCT is used for reconstructing the modified NSCT coefficients for enhanced image. Last stage of our work remains to equalize the histogram of an image for improve the contrast and it is done by using WMSHE (Weighting Mean-Separated Sub-Histogram Equalization). The proposed method is illustrated in Figure 1.
Figure 1 Functional diagram of proposed technique

A. NON-SUBSAMPLED CONTOURLET TRANSFORM
The main issue of contourlet transform is, it is not shift-invariance because of the presence of up and down sampling process in DFB and LP. The NSCT is designed to fix this issue, it includes non-subsampled pyramid (NSP) and non-subsampled directional filter bank (NSDFB) [7]. Initially in the method, the NSP filters decompose the input image into low and high frequency components. On high frequency components, the NSDFB is executed [7].

B. BILATERAL FILTERING
Tomasi and Manduchi [1] presented the Bilateral Filter. It is performed by the combination of two gaussian filters. First gaussian filter works in intensity domain whereas the second gaussian filter works in spatial domain. The output is a weighted average of the input as it is a non-linear filter. The bilateral filter output for a pixel is defined as follows for an ultrasound image.

\[ I_s = \frac{1}{K(s)} \sum_{p \in \Omega} (p - s) g(I_p - I_s) I_p \]

where \( K(s) \) is a normalization term.

\[ K(s) = \sum_{p \in \Omega} f(p - s) g(I_p - I_s) \]

where \( g \) uses a gaussian filter in the intensity domain that symbolizes the range filter and \( f \) uses a gaussian filter in the spatial domain which indicates the domain filter.

Mathematically domain filtering can be expressed as:

\[ I_s = \frac{1}{K(s)} \sum_{p \in \Omega} (p - s) g(I_p - I_s) I_p \]

where

\[ f(p - s) = \exp\left(-\frac{(p - s)^2}{2\sigma_d^2}\right) \]

\( f(p-s) \) measures the spatial closeness between the neighborhood center and the adjacent point.

Range filtering is defined as follows

\[ I(s) = \frac{1}{k_r(s)} \sum_{p \in \Omega} g(I_p - I_s) I_p \]

where

The photometric similarity between the center pixel and its adjacent point \( p \) is measured by \( g(I_p - I_s) \).

\[ g(I_p - I_s) = \exp\left(-\frac{(I_p - I_s)^2}{2\sigma_d^2}\right) \]
Normalized constant in this case is

\[ K_r(s) = \sum_{p \in \Omega} g(I_p - I_0) \]

C. WEIGHTED MEAN SEPARATED SUB-HISTOGRAM EQUALIZATION

Weighted mean separated sub-histogram equalization method performs a separation of histogram based on weighting mean function [9] and equalizing sub-histograms for contrast enhancement.

3. PERFORMANCE METRICS

To show improvement in contrast enhancement various parameters are measured in terms of structural similarity index matrix (SSIM), PSNR and Absolute Mean Brightness Error (AMBE). SSIM is mainly used for checking similarity between original and filtered images.

\[
SSIM = \left( \frac{2XY + k_1}{X + Y} \right) \left( \frac{2\sigma_{xy} + k_2}{\sigma_x^2 + \sigma_y^2} \right)
\]

Where \( k_1 = L^2 C_1 \)
\( k_2 = L^2 C_2 \)

L is the active range of the pixels and the value of \( C_1 \) and \( C_2 \) should be greater than one.

PSNR is defined as

\[
PSNR = 10 \log_{10} \left( \frac{255^2}{MSE} \right)
\]

Absolute Mean Brightness Error is a system of measurement that measure the brightness protection. A lower value of Absolute mean brightness error indicates a mean brightness of enhanced image nearer to the original image. It is calculated as follows:

\[
AMBE = s(x, y)_{mean} - t(x, y)_{mean}
\]

Where \( s(x, y)_{mean} \) is the mean of original image \( s(x, y) \) and \( t(x, y)_{mean} \) is the mean of the enhanced image in contrast \( t(x, y) \).

4. RESULTS AND DISCUSSION

Herein we performed few systems of measurement to test the performance of the proposed technique with clinical ultrasound images.
Improvement of contrast enhancement are compared with Histogram Equalization (HE), contourlet transform, Contrast Limited Adaptive Histogram Equalization (CLAHE)and the proposed method of non-subsampled contourlet transform with Histogram Equalization.

The result analysis is done by determining the three parameters [SSIM, Peak signal to Noise Ratio, AMBE]. The underlying tables shows performance analysis for various methods for ultrasound images.

Table 1: SSIM obtained for different methods

<table>
<thead>
<tr>
<th>Ultrasound Images</th>
<th>Contourlet</th>
<th>HE</th>
<th>CLAHE</th>
<th>Proposed Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac</td>
<td>0.581</td>
<td>0.004</td>
<td>0.244</td>
<td>0.998</td>
</tr>
<tr>
<td>Kidney</td>
<td>0.524</td>
<td>0.001</td>
<td>0.164</td>
<td>0.998</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.458</td>
<td>0.002</td>
<td>0.140</td>
<td>0.997</td>
</tr>
</tbody>
</table>

Table 2: PSNR obtained for different methods

<table>
<thead>
<tr>
<th>Ultrasound Images</th>
<th>Contourlet</th>
<th>HE</th>
<th>CLAHE</th>
<th>Proposed Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac</td>
<td>25.14</td>
<td>12.06</td>
<td>12.06</td>
<td>44.23</td>
</tr>
<tr>
<td>Kidney</td>
<td>24.93</td>
<td>14.15</td>
<td>14.15</td>
<td>42.33</td>
</tr>
<tr>
<td>Thyroid</td>
<td>24.98</td>
<td>14.20</td>
<td>14.20</td>
<td>43.02</td>
</tr>
</tbody>
</table>

Table 3: AMBE obtained for different methods

<table>
<thead>
<tr>
<th>Ultrasound Images</th>
<th>Contourlet</th>
<th>HE</th>
<th>CLAHE</th>
<th>Proposed Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac</td>
<td>0.0008</td>
<td>0.0005</td>
<td>0.0005</td>
<td>0.0001</td>
</tr>
<tr>
<td>Kidney</td>
<td>0.0008</td>
<td>0.0003</td>
<td>0.0003</td>
<td>0.0002</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.0009</td>
<td>0.0004</td>
<td>0.0004</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

The performance of the proposed method was evaluated using SSIM, PSNR and AMBE. The image which is given as an input is a cardiac ultrasound medical image and contrast enhancement was performed using the proposed technique and compared with Histogram Equalization, contourlet transform, and CLAHE. Table 1 shows SSIM estimate of the proposed techniques improved when performed with Histogram Equalization, contourlet transform and CLAHE. Three different images such as cardiac, kidney, and thyroid ultrasound images has been taken into consideration. Table 2 shows Peak Signal to Noise Ratio values, which designates the planned non-subsampled contourlet transform with Histogram Equalization technique shows advancement.
when performed with the existing methods. Table 3 specifies AMBE values, which shows the performance of the proposed non-subsampled contourlet transform with bilateral filter method is better than Histogram Equalization, contourlet transform and CLAHE.

Figure 2 illustrates the input ultrasound cardiac image. The output image of contourlet transform is shown in Figure 3. The output images of AE and CLAHE are shown in Figures 4 and 5 respectively. Figure 6 shows the output of the proposed non-subsampled contourlet transform with bilateral filter method. The contrast enhanced image of the proposed method is visually pleasing when compared to the other existing methods.
5. CONCLUSION

In this article, we introduced a technique for enhancing the medical ultrasound cardiac, kidney and thyroid images based on NSCT with Histogram Equalization. The technique WMSHE used NSCT for decomposing the image, bilateral filter for smoothing the edges present in the coefficients, WMSHE is processed for getting the enhanced image. WMSHE enhance the contrast by splitting the histogram of the image. The proposed technique indicates better performance than other existing systems. Implementation was done on MATLAB and the execution of our technique is compared with the performance of current techniques by using several metrics like, SSIM, PSNR and AMBE. On our future work, we planned to improve the proposed technique with this same method or may improve the contrast enhancement process of our work with some other methods that are best on that period.

6. REFERENCES


