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Contrast Enhancement Technique for CT Images

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ABSTRACT

The images obtained by computed tomography (CT) scanning are gray scale images, in which gray level shades are almost similar around the tissue. CT images must be enhanced for easy visualization of the lesion or tumor. This paper proposes a contrast enhancement technique for medical CT images, based on modification of histogram equalization technique. Modification is done by adding a constrained variable offset to the transformation function of global histogram equalization. This constrained variable offset helps to preserve the mean brightness of the image, which prevents the global outlook of CT image. Texture of structural part of CT images was enhanced by this algorithm, due to which tumor or infected region is easily visible. The proposed technique was applied on liver CT images containing tumor and its performance was evaluated by subjective evaluation and three quantitative measures.

Keywords: global histogram equalization, constrained variable offset, cumulative distributive function, transformation function.

1 Introduction

Enhancement of computed tomography (CT) medical images is needed to visualize the tumor and disease portion of image correctly and easily. CT images have low contrast in the gray level distribution of tissue part in the image, because of that, small tumors and infected parts are not clearly visible. Texture of the CT images is needed to be improved to visualize the disease, especially small tumors. Texture can be enhanced by enhancing the contrast of the image (without taking background in consideration). The proposed technique helps in enhancement of texture of the CT image so that tumor region is easily visible to the radiologist with less fatigue.

There are many contrast enhancement techniques in literature, global histogram equalization (GHE) is one of the most common techniques, but the main drawback of this technique is artifacts because of over enhancement [1]. The main purpose of this technique is to make uniform histogram distribution of the image. Due to this, histogram of the enhanced image sometimes over stretched and global outlook of image is disturbed, which is not desirable in images. Local histogram equalization (LHE) is extension of histogram equalization (HE) and used to enhance the local details of the image, which GHE fails to do [1,2]. LHE also enhances the noise with the local details. Dynamic histogram equalization (DHE) [3] technique is also based on conventional HE. DHE divides the histogram of image into sub-parts according to the local minima and equalize each part after assigning them specific gray values.

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Constrained variational histogram equalization (CVHE) is a very effective technique used for contrast enhancement with preserving the global appearance of the image [4, 5]. In this technique variational approach of histogram equalization is used with a constraint that preserves the mean brightness. A weighting mean- separated sub- histogram equalization (WMSHE) technique enhances the contrast by separating the histogram of image based on weighting mean function and equalizing each sub part by its small scale value [6]. This technique also preserves the overall luminance of the image. The range limited bi-histogram equalization (RLBHE) technique is also proposed to maintain the global look of the enhanced image by preserving the mean luminance of the image [7]. This technique divides the histogram into two sub parts according to a threshold in order to minimize the intra class variance. Due to this the object is separated from background and contrast is enhanced separately. Contrast limited adaptive histogram equalization (CLAHE) technique enhances the contrast by dividing the image matrix into tiles (blocks), after enhancing the contrast of all tiles separately, it combines the neighboring tiles using bilinear interpolation to avoid the blocking effect [8].

The proposed technique, histogram equalization with constrained variable offset (HECVO) is also based on the histogram equalization. This technique uses the conventional transformation function of HE to enhance the contrast, by adding a variable offset to it, which will preserve the mean brightness of the enhanced image.

2 Global Histogram Equalization Technique

Let hi(r) and ho(s) are the normalized histogram of the input image and output image (enhanced image) respectively, where r and s are the normalized random variables for gray level. A transformation function is used to map the gray level rx of input image to gray level sx of output (enhanced) image [1], where r, s ϵ [0, L]:

$$s = T(r) \tag{1}$$

The transformation function used for image enhancement in GHE is cumulative distribution function (CDF):

$$s = T(r) = \sum_{x=0}^{r} hi(x) \quad \text{for r=0,1....L} \tag{2}$$

For gray scale images (8-bit images) L is equal to 255.

3 Proposed Technique

The proposed technique is histogram equalization with constrained variable offset (HECVO). This technique is divided into two stages:

1. Contrast enhancement using transformation function of global histogram equalization.
2. Preserve the mean brightness of image by adding the constrained variable offset to the transformation function.

In first stage, transformation function of histogram equalization is obtained using CDF, and applied to image to enhance the contrast of the input image. Contrast of the image is enhanced, but the global outlook changes and mean brightness of image is not equal or closer to the original image. Therefore, the transformation of GHE is taken as the base function of the algorithm and an offset is added to it in second stage.

In second stage, mean brightness of the output or enhanced image is preserved, so the image retains its global outlook. To achieve this objective Δλ constrained variable offset is added to the transformation of HE. This offset is added or subtracted according to the output image brightness, if output image is brighter than the input image then Δλ is subtract acted from the original transformation function and if the output image is darker than the input image then Δλ is added to transformation function in order to make the mean brightness of the output image closer or equal to the input image. When global histogram equalization is applied to the CT images, it produces brighter images than original. It implies that for CT images offset is subtracted from the original transformation function, so new transformation function is:

$$T(r) = \sum_{x=0}^{r} hi(x) - \Delta\lambda \tag{3}$$

Δλ is constrained variable offset, it controls the over stretching produced by the global HE and it varies according to the histogram values of the input image. It is calculated as follows:

$$\Delta\lambda = |k| - \left(\frac{|k|}{L+1} \times x \right) \tag{4}$$

Where x is bin value of gray scale histogram of the input image, k is a constant obtained iteratively according to the mean brightness difference ΔM. k is initiated by any arbitrary value, say k=1, then apply the transformation function in eq.(3) and calculate the mean brightness difference ΔM. Iteratively increase or decrease the value of k (according to the mean brightness of output image) till the mean brightness difference is minimized. Mathematical formula for mean brightness difference is:

$$\Delta M = \frac{\left(\sum_{x=0}^{r} x \times hi(x) - \sum_{x=0}^{r} T(r) \times hi(x) \right)}{m \times n} \tag{5}$$

Where (m×n) is size of the original image.

The transformation function of proposed technique performs controlled stretching of histogram of image for contrast enhancement with global outlook similar to the original image.

4 Performance Evaluation Methods

The proposed algorithm is applied to the liver CT images. The performance evaluation is done subjectively by visual inspection of radiologist and quantitative analysis (objective analysis) is done by calculating three measures: root mean square contrast (RMSC) [9], root mean square error (RMSE) [4], absolute mean brightness error (AMBE) [4].

RMSC is used to measure the contrast value of the image, higher contrast value shows the high contrast enhancement. Mathematical formula for RMSC is:

$$RMSC = \sqrt{\frac{1}{m \times n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left(I(i,j) - \bar{I}\right)^2} \quad (6)$$

Where ($m \times n$) is the size of the mage, $\bar{I}$ is the average intensity of all pixel values in the image. The image I is assumed to have its pixel intensities normalized in the range [0, 1].

RMSE is used to quantify the distortion or change produced by the enhancement operator. Lower value of RMSE shows low distortion in the image. Increment in contrast value is also considered as distortion, but this distortion is required for enhancement of image. Therefore, distortion is produced with contrast enhancement but this distortion must not so high that image overall appearance changes. Mathematical formula for RMSE:

$$RMSE = \left(\frac{1}{m \times n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left(I(i,j) - I^*(i,j)\right)^2\right)^{\frac{1}{2}} \quad (7)$$

Where I and I^* are the original and enhanced images, respectively.

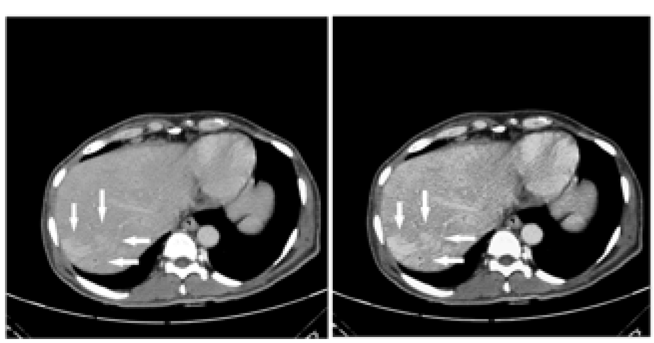
AMBE is defined as the difference between mean brightness of input image and mean brightness of output image. To preserve the global appearance of image, the AMBE value should be low. Mathematical formulas for AMBE:

$$AMBE = \left|\mu_o - \mu_i\right| \quad (8)$$

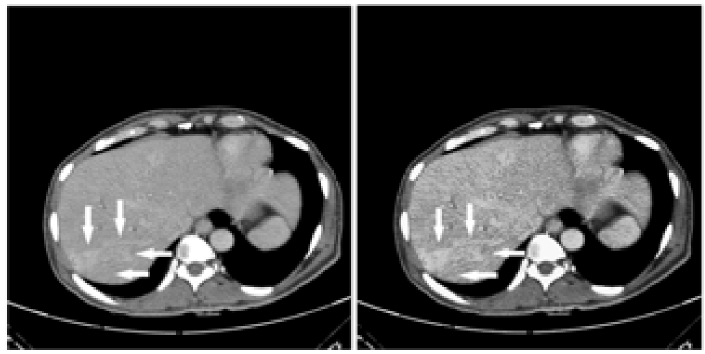
Where μ_i *and* μ_o are mean brightness of the input and output images, respectively.

5 Results and Discussion

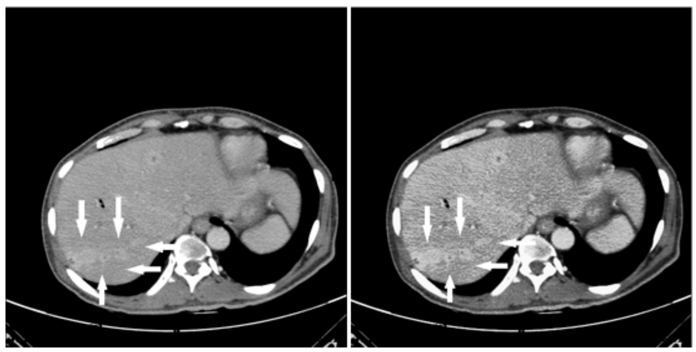
The proposed technique is evaluated both subjectively and quantitatively on a data set containing 75 CT images, out of which some CT images are shown in Fig. 1. Arrows in the images point to the infected portion of tissue. The size of images is 514×514 pixels. The data set of CT images is taken from the MAX hospital, Delhi, India. Processed techniques are implemented in MATLAB version 7.10. Visual inspection of enhanced images shows that the texture of the liver tissues is enhanced and image details are more clear, due to which tumor is easily visible as compared to original image. The enhanced images are assessed and approved by radiologist. The subjective evaluation is supported by three quantitative measures shown in Table 1.



(a) (b)



(c) (d)



(e) (f)

Figure 1: (a), (c), (e) are original CT images of liver and (b), (c), (d) are enhanced CT images of liver

The RMSC, RMSE and AMBE measures are compared for three different contrast enhancement techniques shown in Table 1. Mean and variance of three quantitative measures of 75 CT images are calculated for three techniques i.e. HECVO, HE, CLAHE.

Table 1: Performance comparison of contrast enhancement techniques

Performance measures	HECVO	HE	CLAHE
RMSC	0.2773±0.0888	0.1127±0.02522	0.2892±0.02293
RMSE	7.3407±1.9531	138.7428±128.3671	17.9338±11.2542
AMBE	1.3196±0.5403	132.8548±168.0150	7.1329±13.4152

The RMSC value of HE is lower than HECVO, it implies that HECVO do better contrast enhancement in comparison to HE. The RMSC value of HECVO is slightly lower than CLAHE, but the distortion (RMSE) produced by CLAHE is higher than the HECVO. Contrast enhancement of CT images is required with low distortion, so that image retains its original appearance. Therefore it is clear that HECVO enhances the contrast of image with less distortion in comparison to HE and CLAHE. The AMBE value of HECVO is lowest in comparison to other two techniques, so it can be said that the proposed technique outperforms the HE technique in preserving the mean brightness of the image after processing. CLAHE technique also preserves the mean brightness but HECVO preserves the global outlook of image most significantly. The subjective analysis and quantitative results shows that HECVO enhances the contrast with less distortion and preserves the overall appearance of CT image.

6 Conclusion

The proposed HECVO technique enhanced the contrast of the CT images by preserving its global luminance. After applying HECVO technique the tumor in the CT images are more clearly visible than the original images. Texture of the tissue part of the CT images is enhanced, which is required for better disease diagnosis. Subjective and objective evaluation states that HECVO is suitable algorithm for enhancement of the CT images.

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