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Feedback alfa-rooting algorithm for medical image enhancement

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Abstract

This paper presents a new combined local and global transform domain-based feedback image enhancement algorithm for medical diagnosis, treatment, and clinical research. The basic idea in using local alfa-rooting method is to apply it to different disjoint blocks with different sizes. The block size and alfa-rooting parameters driven through optimization using the Agaian's cost function (image enhancement non-reference quality measure). The presented new approach allows enhancing MRI and CT images with uneven lighting and brightness gradient by preserving the local image features/details. Extensive computer simulations (CS) on real medical images are offered to gage the presented method. CS shows that our method improves the contrast and enhances the details of the medical images effectively compared with the current state-of-art methods.

Introduction

The goal of image enhancement (IE) is to improve certain features/details of an image and to improve its visual quality. IE is one of the key procedures in many image processing (image segmentation, feature extraction), medical imaging (such as X-ray, CT, and MRI) and computer vision (target, object, and text detection, segmentation, registration, and recognition) applications [1-3]. In general, X-ray, CT, and MRI images are often affected by blurriness, lack of contrast, which are very important for the accuracy of medical diagnosis and treatment. Recently, several image enhancements both on special (Global Histogram Equalization (GHE), Limited Adaptive Histogram Equalization (CLANE) methods) and transform domains (Global Alfa-Rooting) have been developed [4-6]. Each of this method has own advantages and limitations. For example, most of global transform domain methods may introduce some artifacts by enhancing the background noise, may over-enhance and under-enhance images, may not work well on irregular lighting and brightness images and may not preserve the local image features/details.

This paper presents a new combined local and global transform domain-based feedback image enhancement algorithm for medical diagnosis, treatment, and clinical research. The basic idea in using local alfa-rooting method is to apply it to different disjoint blocks with different sizes. The block size and alfa-rooting parameters driven through optimization using the Agaian's cost function (image enhancement non-reference quality measure). The presented new approach allows enhancing MRI and CT images with uneven lighting and brightness gradient by preserving the local image features/details. Extensive computer simulations (CS) on real medical images are offered to gage the presented method. CS shows that our method improves the contrast and enhances the details of the medical images effectively compared with the current state-of-art methods. As well, the results demonstrate that the proposed approach improves both contrasts and suppress noise effectively. Finally, the presented method may be used as a new "big medical data" tool for computer-assisted detection and diagnosis developer and by the clinical researcher.

Related Work

Most of the image enhancement methods are based on histogram analysis and modification: histogram equalization, histogram matching, contrast stretching, intensity adjustment, etc. [7,8]. One of the most popular image enhancement methods is histogram equalization. It is a global processing approach, so the entire tone of the image has been changed like more bright or dark image.

Adaptive histogram equalization (AHE) is an image processing technique used to improve contrast in images [4]. An adaptive version of this algorithm called contrast limited adaptive histogram equalization (CLAHE) [5].

The Weighted Bi-Histogram Equalization method uses the decomposed sub-images based on the distributed area ratio [9].

The frequency domain enhancement methods such as DCT, Fourier use transformation in the frequency domain [10, 11]. Alpha rooting is one of the more popular enhancement methods [3, 6].

Each of these methods has strong and weak points. Hence, the combination of the above methods is used to enhance the image through transform histogram mapping technique.

So, the weaknesses of traditional methods are [12]:

- Extremely sensitive to parameters.
- Fails to enhancement on irregular lighting and brightness images and may not preserve the local image features/details.
- For point processing spatial information completely lost.
- A global processing approach has been changing the entire tone of the image like more bright or dark image.
- Extend the dynamic range of an image in local regions, what leading to artifacts and overall tonal change of the image.
- Frequency domain methods introduce certain artifacts which called "objectionable blocking effects and they cannot simultaneously enhance all parts of the image very well.
- Most of global transform domain methods may introduce some artifacts by enhancing the background noise, may over-enhance and under-enhance images.

The objective of our work is to develop a new medical image enhancement algorithm based on combined local and global image processing.

Proposed method

In this paper, we propose a novel contrast enhancement algorithm via structure-texture decomposition [Figure 1]. First, we develop the decomposition method to separate an input image into structure and texture components using the total variation minimization scheme [13]. We use algorithm of total variation minimization proposed by Antonin Chambolle in [14].

An image can be modelled as a function $X: \Omega \rightarrow \mathbb{R}$ where $\Omega \subseteq \mathbb{R}^2$. The general idea in order to decompose an image into $S + T$ is given by Meyer's model [15]:

$$inf\{F_1(sS) + \lambda F_2(T): X = S + T\}.$$

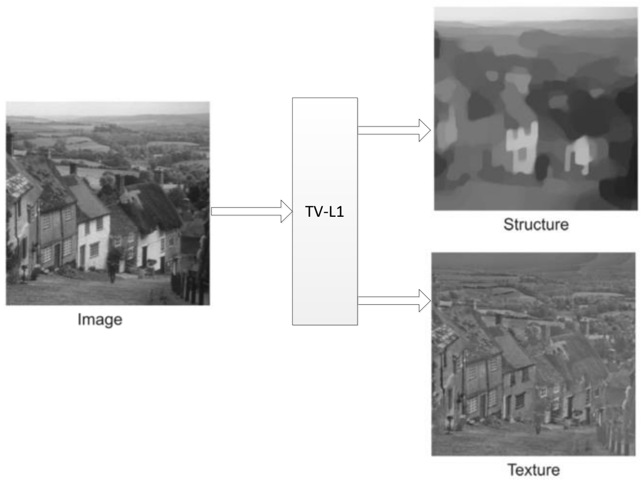


Figure 1. Image decomposition to structure and texture

Second, we propose an image enhancement algorithm using the results of the decomposition. The proposed algorithm separately enhances the structure and the texture using combined local and global image processing. The basic idea is to apply α-rooting image enhancement approach for different image blocks. For this purpose, we split image in moving windows on disjoint blocks with different size (8 by 8, 16 by 16, 32 by 32 and, i.e.) (Fig. 2). The local processing uses for texture image with block size 8 by 8 and 16 by 16. For the structure image, we use global processing.

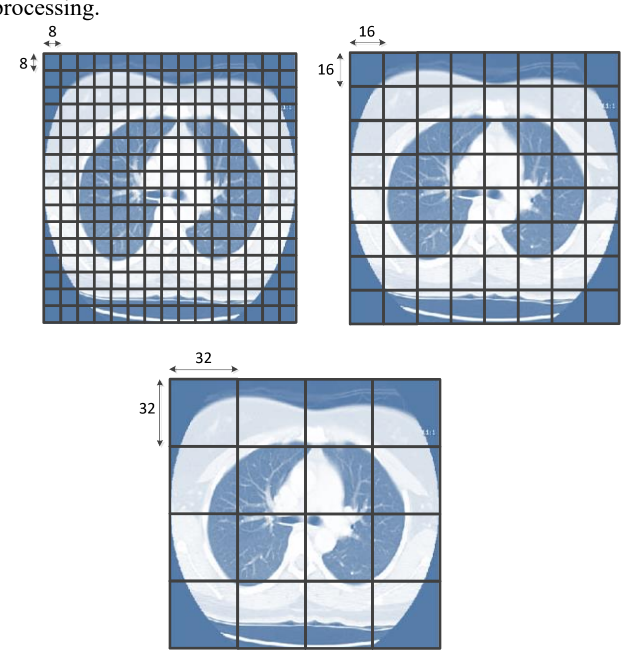


Figure 2. The image splitting

The procedure for the proposed algorithm is expressed as following steps:

Input: Original image.

Step 1: Image decomposition.

Step 2: Image splitting.

Step 3: Enhancement processing.

Step 4: The measure of image enhancement (EME) calculation.

Step 5: Weighted average.

Output: Enhanced image.

The block diagram of the proposed enhancement algorithm is shown in figure 3.

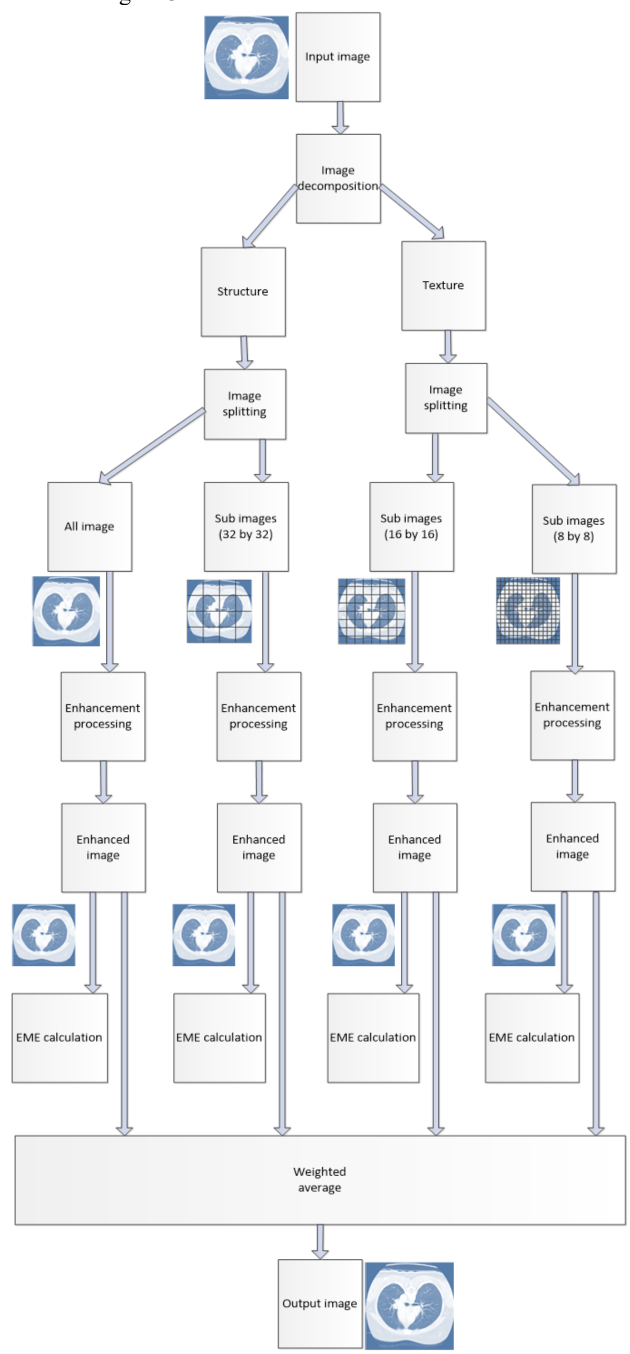


Figure 3. Block diagrams of the proposed algorithm

For proposed image enhancement method, we use the frequency domain. One simply performs the transform of the image to be enhanced, then manipulated the transform coefficient, and then perform the inverse orthogonal transform. Image transforms give the spectral information about an image, by decomposition of the image into spectral coefficients that can be modified (linearly or non-linearly), for enhancement and visualization. So, transform-based enhancement algorithm base on the α-rooting and magnitude reduction method (Fig. 4).

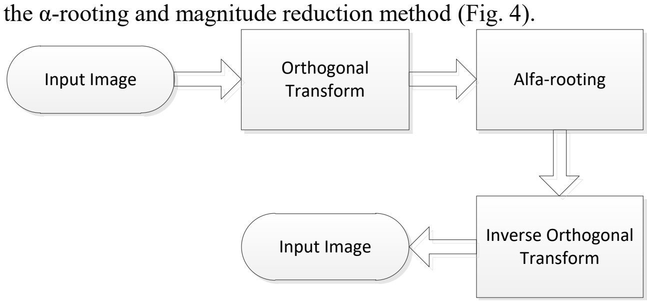


Figure 4. Alfa-rooting image enhancement algorithm

For every block, we use transform-based enhancement algorithm base on the α-rooting and magnitude reduction method [6]:

$$\hat{X}(p,s) = X(p,s) \times |X(p,s)|^{\alpha-1} = |X(p,s)|^{\alpha} \times e^{i\theta(p,s)},$$

where $X(p,s)$ is the transform coefficients of the image,
α is a user defined operating parameter,
$\theta(p,s)$ is the phase of the transform coefficients.

The α-rooting transform depends on the parameter α. We are choosing the best (optimal) enhancement image through optimization of measure enhancement (EME) introduced by Agaian [16]:

$$EME_{k_1,k_2} = max\left(\frac{1}{k_1 \times k_2} \times \sum_{l=1}^{k_1} \sum_{k=1}^{k_2} 20 \times log \frac{X^{\omega}_{max;k,l}}{X^{\omega}_{min;k,l}}\right),$$

where $X^{\omega}_{max;k,l}$ and $X^{\omega}_{min;k,l}$ respectively are the minimum and maximum of the image $x(n,m)$ inside the block $\omega_{k,l}$.

For every patch of the image, we apply α-rooting algorithm with the value of alpha that maximizes the value of EME.

We calculate EME for every enhanced image. The resulting image is a weighted mean of all processing blocks:

$$\tilde{X} = \tilde{X}_1 \times W^{\tilde{X}_1} + \tilde{X}_2 \times W^{\tilde{X}_2} + \tilde{X}_3 \times W^{\tilde{X}_3} + \tilde{X}_4 \times W^{\tilde{X}_4}.$$

Finally, we obtain a visually improved output image by adding the enhanced structure and texture components.

Experiments

We compare the classical well-known algorithms histogram equalization and CLAHE and proposed. Figures 5-8 demonstrate the image enhancement results obtained by various algorithms respectively (a – original image; b - the enhanced image by the histogram equalization; c - the enhanced image by the CLAHE; d - the enhanced image by the proposed method).

The examples demonstrate the effectiveness of proposed image enhancement algorithm on different images with a qualitative opinion in a human observer study. These images have visually more contrast and details. The artifacts are nullified, and the fine details are clearly brought out. Here, the contrast illumination stands out.

Figure 5. Examples of image enhancement «Hand»

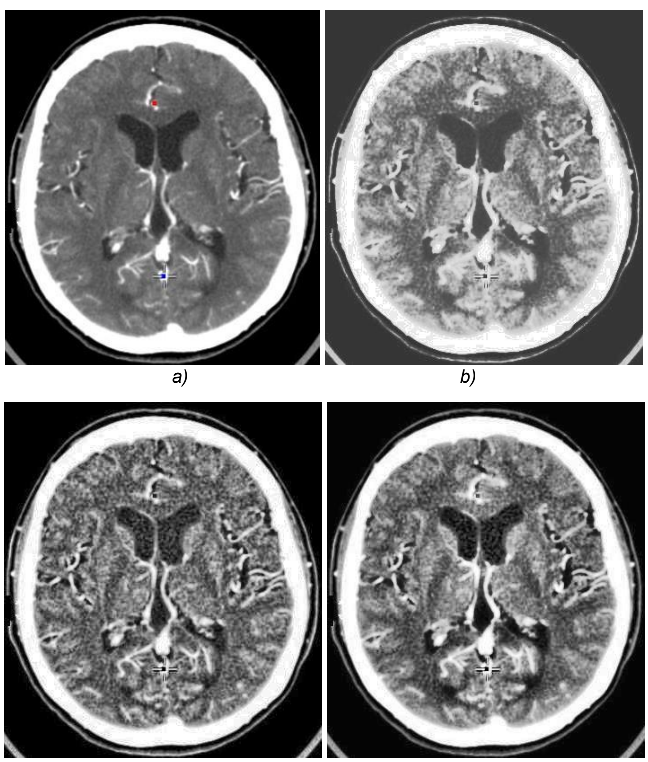
Table 1 represents the set of EME values. The proposed method gets the highest EME value in each case, displaying its advantage over various other enhancement techniques. The new approach is better than the existing ones because it combines their strengths and overcomes their weaknesses.

Table 1. Comparison of resulting EME's of different enhancement methods

Images	*Original*	*Histogram equalization*	*CLAHE*	*Proposed method*
«Hand»	16,47	14,7	5,44	**18,59**
«Body»	12,3	32	16,84	**36,43**
«Brain»	47,81	52,01	30,84	**56,53**
«Vessels»	24,51	31,36	16,96	**33,77**

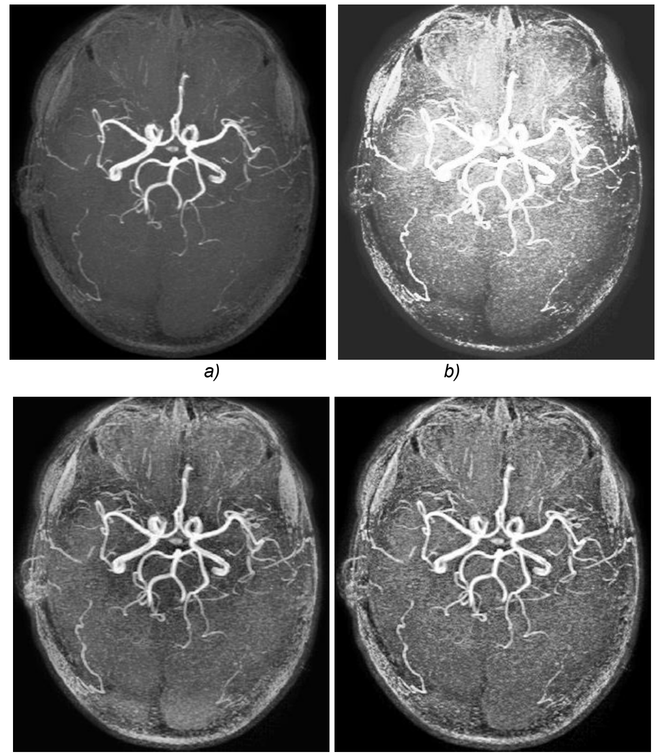
a) b) c) d)

Figure 6. Examples of image enhancement «Body»



a) b) c) d)

Figure 7. Examples of image enhancement «Brain»



a) b) c) d)

Figure 8. Examples of image enhancement «Vessels»

Conclusions

We present a new combined local and global transform domain-based feedback image enhancement algorithm for medical diagnosis, treatment, and clinical research. The basic idea is to apply α-rooting image enhancement approach for blocks on texture and structure images with different size. The block size and alfa-rooting parameters driven through optimization using the image enhancement non-reference quality measure. The proposed image enhancement results compare favorably against other state-of-the-art approaches.

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Viacheslav Voronin was born in Rostov (Russian Federation) in 1985. He received his BS in radio engineering from the South-Russian State University of Economics and Service (2006), his MS in radio engineering from the South-Russian State University of Economics and Service (2008) and his Ph.D. in technics from Southern Federal University (2009). Voronin V. is a member of Program Committee of conference SPIE. His research interests include image processing, inpainting, and computer vision.

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