

Image Enhancement Using Splitting α -Rooting Method in Wavelet Domain

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Abstract: This paper will present an enhancement technique based upon splitting α -rooting method in wavelet domain. Wavelets transform concentrate most of the energy in the approximation coefficient. In splitting signal, a two-dimensional image is represented uniquely by a set of one-dimensional signal, which carries the spectral information of the image at frequency points of specific sets. Using splitting α -rooting method in the approximation coefficient of wavelet transform, the image enhancement procedure can be reduced to processing splitting signals and the process requires only a few spectral components of the image. A measure of enhancement based on contrast measure with respect to transform will be used as a tool for evaluating the performance of the proposed enhancement technique and for finding optimal values for variables contained in the enhancement. The algorithm's performance will be compared quantitatively to classical histogram equalization and splitting α -rooting method using the aforementioned measure of enhancement.

1. Introduction

Image enhancement technology plays a very important role in the field of image processing. Digital image enhancement is necessary to improve the visual appearance of the image or to provide a better transform representation for future automated image processing such as image analysis, detection, segmentation and recognition [1-2]. By enhancing some information and restraining other information selectively, it can improve image visual effect. Image enhancement is a technique which reduces image noise, remove artifacts, and preserve details. Its purpose is to amplify certain image features for analysis, diagnosis and display. Technique can be performed by either suppressing the noise or increasing the image contrast. Image enhancement techniques can be classified into spatial domain enhancement and transform domain enhancement.

Spatial domain enhancement techniques deal with the image's intensity values directly. Linear contrast stretching and global histogram equalization are two of the most widely used non transform based uniform enhancement technique. Histogram equalization attempts to alter the spatial histogram of an image to closely match a uniform distribution [3]. Adaptive histogram equalization [4], contrast-limited adaptive histogram equalization (AHE) [5] belongs to spatially non uniform enhancement technique. Histogram equalization suffers from the problem of being poorly suited for retaining local detail due to its global treatment of the image. Histogram equalization tends to over-enhance the image contrast if there is a high peaks in the histogram resulting in a undesired loss of visual data,

of quality and of intensity scale [6-7]. Also small scale details that are often associated with the small bins of the histogram are eliminated. AHE applies locally varying gray-scale transformation on each small region of the image. This method does not completely eliminate noise enhancement in smooth regions. A survey of the spatial domain enhancement techniques can be found in [8-9].

In case of transform domain enhancement techniques, the image intensity data are mapped into a given transform domain by using transform such as 2-D discrete cosine transform (DCT), Fourier transform and other fast unitary transforms. The basic idea in using this technique is to enhance the image by manipulating the transform coefficients. One of the well-known and proven enhancement techniques is alpha rooting, which was modified later on into log-alpha-rooting, modified unsharp masking and filtering [10-16] as well as methods based on wavelet transforms [17-19]. The main disadvantage in using the alpha rooting method relates to the difficulty of selection of the value of parameter alpha. This value should be chosen in an optimal way to enhance all parts of the image very well. Image enhancement using splitting α -rooting method with tensor representation is presented in [20]. In tensor representation, an image is splitted to 1-D signal and can be used for image enhancement. This method uses two 1-D N point DFTs instead of two 2-D DFTs in the traditional α -rooting method. Transform based image enhancement techniques suffers from some disadvantages such as they introduce certain objectionable artifacts, they cannot simultaneously enhance all parts of the image very well and it is difficult to automate the image enhancement procedure. The other drawbacks of all of the above methods is that the brightness is changed and the enhanced images look far from natural and the extend of enhancement is not controllable.

In this paper, image enhancement using splitting α -rooting method in wavelet domain is presented. This method uses the advantages of splitting signal in wavelet domain. The wavelet analysis is capable of providing both the space and frequency information simultaneously, hence giving a space frequency representation of the image. Wavelets transform concentrate most of the energy in the approximation coefficient [21]. Splitting α -rooting is applied to approximation of the wavelet transformed image which requires less splitting signal components for enhancement and gives better performance compared to generalized histogram equalization method and enhancement using only splitting α -rooting method with respect to EME (a measure of enhancement)

The rest of the paper is organized in the following way. In Section 2 frequency domain method of splitting signal is

presented. Section 3 discusses about splitting α -rooting enhancement method in wavelet domain. Section 4 gives description about performance measure of enhancement. Section 5 discusses about some experimental results. Section 6 concludes the experiments and algorithm.

2. Frequency Domain Method of Splitting Signal

A high quality enhancement can be achieved by processing only a few splitting signals [20]. In this method 2-D DFT can be split into 1-D DFTs. The 2-D DFT of an image $f = \{f_{n,m}\}$ of size $N \times N$ is defined by

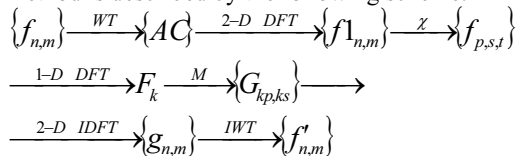
$$F_{p,s} = \sum_{n=0}^{N-1} \sum_{m=0}^{N-1} f_{n,m} \left(\exp \left(\frac{-2\pi j}{N} \right) \right)^{np+ms} \dots\dots\dots(1)$$

Frequency point (p,s) are from the set $X = \{(p,s); p,s=0:(N-1)\}$, where $p=0:(N-1)$ is an integer.

The set X can be covered by a family of subset $T_{p,s}$ where $T_{p,s} = \{(0,0), (p,s), (2p,2s), \dots, ((N-1)p, (N-1)s)\}$ such that the 2-D DFT of the image $\{f_{n,m}\}$ at each set of frequency point $T_{p,s}$ becomes the 1-D DFT of a 1-D signal $f_{Tp,s}$, which is the splitting signal of the image [1]. The splitting signal $f_{Tp,s} = \{f_{p,s,0}, f_{p,s,1}, \dots, f_{p,s,N-1}\}$ carries the spectral information of the image at frequency points of $T_{p,s}$. Here two parameters relate to frequency and one relates to time.

3. Splitting α -Rooting Enhancement in Wavelet Domain

Image processing is an important application field of wavelet analysis. Signal or image can be expanded according to wavelet base and the extending level is determined according to image property and processing demand. The calculation quantity should be controlled and satisfy the need for real-time processing. When the wavelet analysis is used in image processing, the image signal whether in time domain or in spatial domain will be transformed in wavelet domain and then the multi-level wavelet coefficients can be obtained. The coefficients will be analyzed and processed using different methods according to various application conditions. The retransform will be done at last and the enhanced image is obtained. We used splitting α -rooting method of image enhancement on the approximation coefficients. The method is described by the following scheme:



Where $f_{n,m}$ is the input image, WT is wavelet transform, AC is approximation coefficient, χ is splitting signal, M is the operator used to manipulate transform coefficients in α -rooting method, $G_{kp,ks}$ is the result after manipulation and $f'_{n,m}$ is the enhanced image.

First of all we take the wavelet transform of the input image which results four sub-band coefficient images. Wavelet transform produces approximation coefficients and

detail coefficients. After wavelet transform most of the energy is concentrated in the approximation coefficients. Then 2-D DFT is applied to the approximation coefficients and the result is splitted to 1-D signal which will be used for image enhancement using α -rooting.

In case of α -rooting method of image enhancement, the magnitude of the Fourier transform of the image is transformed as $M[|F_{p,s}|] = |F_{p,s}|^\alpha$ at frequency point (p,s) , and parameter α is taken from the interval $0 \leq \alpha \leq 0.99$. The optimal value of α is image dependent and should be adjusted by the user. Thus, components of the Fourier transform $F_{p,s}$, are multiplied by coefficients $C(p,s) = |F_{p,s}|^{\alpha-1}$, where $C(p,s)$ must be real function because we only wish to alter the magnitude information, not the phase information. Next, we need to replace the values of 2-D DFT with enhanced splitting signal using 1-D DFT which results new 2-D DFT at frequency points of the set $T_{p,s}$. Then we perform inverse of 2-D DFT. Last of all, using the enhanced values of approximation and other unchanged details, we perform inverse wavelet transform which gives us the resultant enhanced image.

4. Performance Measure of Enhancement

A processed image can be said to have been enhanced over the original image if it allows the observer to better perceive the desirable information in the image. The improvement in images after enhancement is difficult to measure. There is no universal way to measure which can specify both the objective and the subjective validity of the enhancement method [11]. In practice many definition of contrast measure are used [22]. To measure the quality (or contrast) of images and select the optimal processing parameters, we use the following quantitative measure of image enhancement proposed in [14].

$$EME_{\alpha,k_1,k_2}(\Phi) = \frac{1}{k_1 k_2} \sum_{l=1}^{k_1} \sum_{k=1}^{k_2} 20 \ln \frac{I_{\max,k,l}^w(\Phi, par)}{I_{\min,k,l}^w(\Phi, par) + c} \dots\dots\dots(2)$$

Where an image $x(n,m)$ be split into $k_1 k_2$ blocks, Φ is a given classical orthogonal transform, α is an enhancement parameter, $I_{\max,k,l}^w$ and $I_{\min,k,l}^w$ are the maximum and minimum intensity value in a given block and c is a small constant equal to 0.0001 to avoid dividing by 0.

$EME_{\alpha,k_1,k_2}(\Phi)$ is called measure of enhancement or contrast measure with respect to transform Φ .

5. Experimental Results

We have proposed a method of image enhancement using splitting α -rooting method in the wavelet domain. This method proved a powerful method method for image enhancement. We split the signal having highest energy and use this signal for image enhancement.

This method was investigated to show the performance of proposed method compared to only histogram equalization technique and splitting α -rooting method of image enhancement.

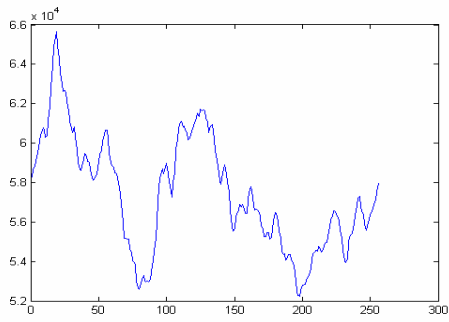


Figure 1. Splitting signal of image 1

Table 1. Comparison of EME of original image, histogram equalized image, using splitting α -rooting method and wavelet based splitting α -rooting method

Image	Original	HE	Splitting α -rooting	WS α -rooting
Image 1	16.16	23.74	30.27	30.33
Image 2	15.01	30.87	43.08	44.01
Image 3	37.24	39.33	43.33	44.37
Image 4	19.05	29.85	21.25	21.32

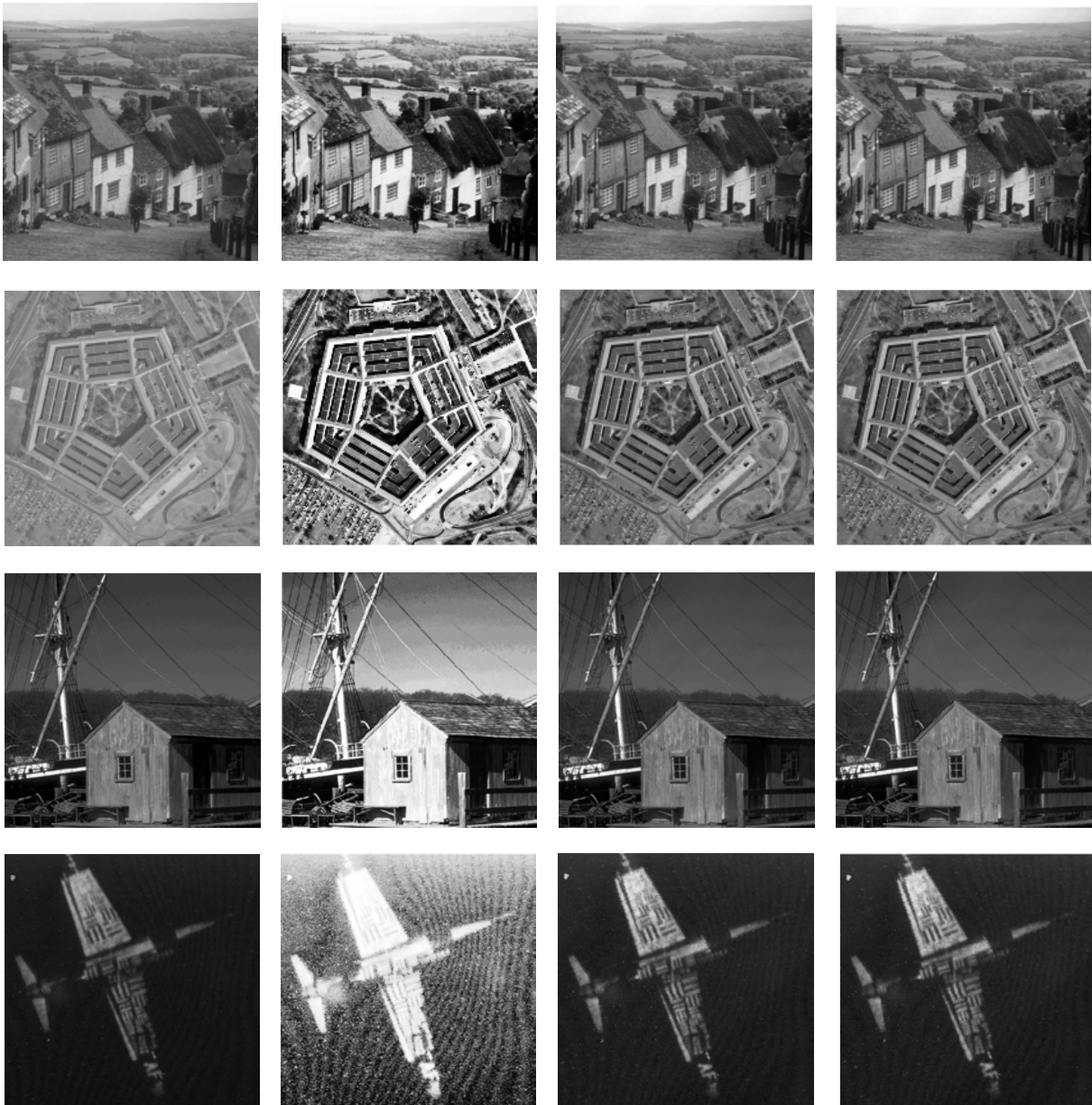


Figure 2. a) Original image, b) Histogram equalized image c) Enhanced image using splitting α -rooting method and d) Enhanced image using wavelet based splitting α -rooting method

Figure (1) shows the splitting signal of the approximation coefficients of the first image of figure (2) using frequency point (1,1) of length 256. Figure (2) shows the results of image enhancement using histogram equalization in part b, splitting α -rooting in part c, and the proposed method in part d with $\alpha=0.94$.

Table 1 shows the numerical results of the proposed method, histogram equalization method and enhancement using only splitting α -rooting method with respect to EME using the test images of figure 2.

Observing these figure 2 and table 1 it can be seen that the proposed method gives better results for image enhancement compared to histogram equalization and splitting α -rooting method. In image 4 EME is lower but visual quality is better than histogram equalized image.

From table 1 and figure 1 it can be observed that the proposed method gives better performance in the field of image enhancement quantitatively and visually.

6. Conclusion

A method of image enhancement based on splitting α -rooting in the wavelet domain is presented in this paper where EME was used as a measure of performance. Because wavelet transform concentrates most of the energy in the approximation coefficients, so applying splitting α -rooting method on approximation coefficients needs less number of points to modify using alpha rooting and hence needs less number of 1-D DFT points. The results of this technique outperform commonly used enhancement technique like histogram equalization and splitting α -rooting. Although this method performs better, it may be slower than others as it requires more computation.

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