HOMOMORPHIC FILTERING APPROACH FOR NARROW BAND IMAGES ENHANCEMENT

V. M. Georgieva

Faculty of Telecommunications, Technical University of Sofia, Bulgaria
1000 Sofia, “Kl. Ohridsky” str.8
E-mail: vesg@tu-sofia.bg

Abstract
The application of narrow band imaging (NBI) in endoscopy improves the accuracy in diagnosis, including reduction in cost and time. It allows better definition between the epithelial surface and the adjacent vascular net via the application of narrow-bandwidth filters to standard white-light endoscopy. The fact, that only selected bandwidths are emitted results in a lower brightness, which requires special high–sensitive dual mode CCDs.

In the paper is presented an approach for NB images enhancement using improved homomorphic filtering. Traditional homomorphic filtering is based on Fourier transform, which has higher resolution in frequency domain and lower resolution in spatial domain. The proposed algorithm includes homomorphic filtering based on wavelet packet transform as first step of improving, and contrast limited adaptive histogram equalization (CLAHE) as the second improving step to adjust its whole luminousness. An adaptive threshold estimation method for image denoising in the wavelet domain is used, for modeling of detail sub-band coefficients. An effective algorithm was treatment by optimization of some parameters of the CLAHE and wavelet transformation on the base of objective quantitative estimation parameters. The main goal is noise reduction and improving the quality of the diagnostic images.

Some results of the experiments with colonoscopy images are presented, which were made by computer simulation in MATLAB environment.

1. INTRODUCTION
Narrow Band Imaging (NBI) uses scattering and absorption properties of human tissue. The penetration depth before being scattered (partly absorbed) depends on the wavelength (colour) of the light. The shorter the wavelength (e.g. blue 415 nm), the earlier it is reflected. Longer wavelengths (e.g. green 540 nm) penetrate deeper. In other words, the image obtained through white light is a composition of slightly different tissue layers. A bright but partially blurred image is the result. Narrow band imaging (NBI) enhances the visualisation of the capillary network and mucosal morphology during endoscopic observation of the gastrointestinal tract. The result is
an image with focus on superficial mucous layers (blue) and the capillary network of the deeper submucosal layer (green). This provides improved visual contrast of the surface structure and fine capillary patterns of the mucous membranes [1].

The fact that only selected bandwidths are emitted results in a lower brightness which requires special high-sensitive dual mode CCDs. The principle of narrow band imaging technology is presented in Figure 1.

Homomorphic filtering can eliminate the nonuniformity luminance distribution of image, and keep its original state. But the property of local spatial domain has not been considered. As a result, enhancement in local contrast is poor. Moreover, the operational speed with the method of homomorphic filtering based on Fourier transform is slower relatively, and it takes up more operational time and space [2].

Wavelet transform has been used in digital image processing widely because of its individual characters, such as multiscale, spatial localization and frequency localization. By this way, both low frequency smooth sub-image and high frequency detailed sub-image with different scale could be obtained [3]. And according to different characters of original image, different coefficient will be used to enhance it [4]. Because of these weakness of traditional homomorphic filtering above, wavelet transform was used instead of Fourier transform to improve operational efficiency. And histogram equalization could be done on image to increase its local contrast [5].

In the paper is presented another approach, homomorphic filtration and noise reduction on the base of wavelet packet transformation (WPT) and contrast limited adaptive histogram equalization (CLAHE). Some quantitative estimation parameters: Noise reduction ratio (NRR), Signal to noise ratio in the noised image ($SNR_R$), Signal to noise ratio in the filtered image ($SNR_F$), Effectiveness of filtration ($E_{FF}$), Peak signal to noise ratio (PSNR) have been analyzed in the paper.
2. BASIC STAGES OF THE ALGORITHM

2.1. Homomorphic Filtering based on WPT

The standard homomorphic filtering uses illumination-reflectance model in its operation. This model consider the image is been characterized by two primary components. The first component is the amount of source illumination incident on the scene being viewed \( i(x,y) \). The second component is the reflectance component of the objects on the scene \( r(x,y) \). The image \( f(x,y) \) is then defined as [6-8]:

\[
f(x, y) = i(x, y)r(x, y)
\]  

(1)

In this model, the intensity of \( i(x,y) \) changes slower than \( r(x,y) \). Therefore, \( i(x,y) \) is considered to have more low frequency components than \( r(x,y) \). Using this fact, homomorphic filtering technique aims to reduce the significance of \( i(x,y) \) by reducing the low frequency components of the image. This can be achieved by executing the filtering process in frequency domain. However, before the transformation is taking place, logarithm function has been used to change the multiplication operation of \( r(x,y) \) with \( i(x,y) \) in Eq.(1) into addition operation.

\[
z(x, y) = ln f(x, y) = ln i(x, y) + ln r(x, y)
\]  

(2)

In the Fourier transform of traditional homomorphic filtering, spatial resolution is lower, and local contrast of image is not increased obviously. Lowpass filtering could reduce noise by smoothing, but the border of image will become to more indistinct. Highpass filtering could enhance the edge of image, but the noise of background will be increased.

Using Fourier transform, the standard homomorphic filtering schema can be presented in Figure 2, where DFT is 2D Discrete Fourier Transform, \( H(u,v) \) is a filter function, \( (DFT)^{-1} \) is 2D Inverse Discrete Fourier Transform and \( g(x,y) \) is the output image. Using Wavelet packet transform, block DFT will be changed with WPT and block \( (DFT)^{-1} \) with IWPT.

![Figure 2. The flowchart of homomorphic filtering](image-url)
The method can propose more complete analysis and provides increased flexibility according to DWT. It has the following important properties:

- A richer presentation of the image, basic on functions with wavelet forms, which consist of 3 parameters: position, scale and frequency of the fluctuations around a given position;
- Numerous decompositions of the image, that allows estimate the noise reduction of different levels of its decomposition;
- Adaptive noise reduction on each level of the decomposition by choice of best tree decomposition and optimal thresholds parameters.

Because the noise of wavelet transform usually concentrate on the state of high resolution, the method is useful to eliminate the noise.

### 2.2. Noise reduction on the base of 2D wavelet packet transformation

The wavelet packet analysis is a generalization of wavelet decomposition that offers a richer image analysis. Based on the organization of the wavelet packet library, it can be determinate the decomposition issued from a given orthogonal wavelets. As this number can be very large, it is interesting to find an optimal decomposition with respect to a conventional criterion. The classical entropy-based criterion by Shannon is a common concept. [9].

Looking for best shrinkage decomposition to noise reduction, two important conditions must be realized together [10]. The conditions are following:

$$E_k(S) = \min, \text{ for } K = 1,2,3...n,$$

(3)

where $E_k$ is the entropy in the level $K$ for the best tree decomposition of image $S$

$$s_{ij} \geq T,$$

(4)

where $s_{ij}$ are the wavelet coefficients of $S$ in an orthonormal basis, $T$ is the threshold of the coefficients.

By determination of the global threshold it is used the strategy of Birge-Massart [11].

This strategy is flexibility. It used spatial adapted threshold that allows to determinate the threshold in three directions: horizontal, vertical and diagonally. In
addition the threshold can be hard or soft. It is proposed to use in addition the Normal Shrink method to calculate the threshold value ($T_N$) only for the detail sub-bands in the best shrinkage decomposition. This threshold can be adaptive and calculated to different sub-band characteristics [12]:

$$T_N = \frac{\beta \sigma^2}{\sigma_Y},$$  \hspace{1cm} (5)

where the scale parameter $\beta$ is computed once for each scale using the following equation:

$$\beta = \sqrt[\log_e(J)]{L_M},$$ \hspace{1cm} (6)

where $L_M$ is the length of the sub-band at $M^{th}$ scale, $J$ is number of decompositions, $\sigma_Y$ is the standard deviation of the sub-band under consideration computed by using the standard MATLAB command.

2.3. Contrast limited adaptive histogram equalization (CLAHE)

Contrast limited adaptive histogram is a technique utilized for improving the local contrast of images. It is a generalization of ordinary histogram equalization and adaptive histogram equalization. CLAHE does not operate on the whole image works like ordinary Histogram Equalization (HE), but it works on small areas in images, named tiles. Each tile's contrast is enhanced, so that the histogram of the output area roughly matches the histogram determined by the 'Distribution' parameter. The adjacent tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The algorithm CLAHE limits the slope associated with the gray level assignment scheme to prevent saturation. This process is accomplished by allowing only a maximum number of pixels in each of the bins associated with the local histograms. After “clipping” the histogram, the clipped pixels are equally redistributed over the whole histogram to keep the total histogram count identical. The procedure of CLAHE is applied to Y component of the selected image that is processing in YUV system as more effectiveness.
3. EXPERIMENTAL RESULTS

The formulated stages of processing are presented by computer simulation in MATLAB, version 8.1 environment with using the IMAGE PROCESSING and WAVELET TOOLBOXES. In analysis are used 20 NB images with size 768x576 from colonoscopy. The original images have been done in jpeg file format. By post processing they are converted in YUV system and bmp format.

The obtained average results from the simulation are presented in Table 1.

<table>
<thead>
<tr>
<th>Basic stages of processing</th>
<th>PSNR   [dB]</th>
<th>SNR_f [dB]</th>
<th>SNR_f [dB]</th>
<th>E_FF [dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homom. filtering based on WPT</td>
<td>32.7106</td>
<td>18.9512</td>
<td>20.8413</td>
<td>1.8901</td>
</tr>
<tr>
<td>CLAHE</td>
<td>33.1274</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</table>

The obtained results from the simulation show that the homomorphic filtering on the base of wavelet packet transformation by using of adaptive threshold estimation method is an effective approach. The values of PSNR and Effectiveness of filtration \( E_{FF} \) are significant and the value of NRR is about 0.3, and shows that the noise is about three times reduced. The variances of the estimations parameters are about ±0.01 by the particular images and depend on quality of the different image.

On Figure 3 is presented the original NB image. In Figure 4 and Figure 5 are shown the filtered image and the image after contrast enhancement respectively. The calculated histograms of the original and processed image are presented in Figure 6.

The obtained results can be compared with other methods such as standard homomorphom filtering and homomorphom filtering on the base on and 2D discrete wavelet transformation (DWT). The obtained average results from the simulation of are presented in Table 2.
Table 2. Simulation results of different methods for homomorphic filtering of NB image

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<tbody>
<tr>
<td>Standard HF</td>
<td>29.4573</td>
<td>0.6598</td>
<td>18.9512</td>
<td>19.5183</td>
<td>0.8671</td>
</tr>
<tr>
<td>HF on the base of DWT</td>
<td>30.9819</td>
<td>0.5094</td>
<td>18.9512</td>
<td>20.1222</td>
<td>1.1710</td>
</tr>
<tr>
<td>HF on the base of DWPT</td>
<td>32.7106</td>
<td>0.3341</td>
<td>18.9512</td>
<td>20.8413</td>
<td>1.8901</td>
</tr>
</tbody>
</table>

Figure 3. The original colonoscopy image

Figure 4. The image after homomorphic filtering on the base on DWPT
Figure 5. The image after CLAHE

Figure 6. Histograms of Y component of NB images: a) original; b) processed

The graphical presentations of the obtained results for PSNR and $E_{FF}$ are given on Figure 7.

Figure 7. Diagrams of $E_{FF}$ and PSNR

The obtained simulation results show that the proposed method is more effectiveness. The value of NRR is about 0.3 and shows that the noise is three times
reduced. The value of NRR by second method, based on DWT is about 0.5 and shows that the noise is two times reduced. The values of PSNR and Effectiveness of filtration ($E_{FF}$) for the proposed method are more sufficient. The experimental results showed enhancement of the image and increasing of image information in consequence of brightness level restoration.

5. CONCLUSION

In the paper is proposed a new and effective approach for NB image enhancement, based on improvement of homomorphic filtering. The complex processing has an effect of brightness and contrast enhancement, noise reduction on the base of WPT, that results in clear vision of the mucosa in colonoscopy images. An adaptive threshold estimation method for noise reduction in the wavelet domain is used, based on combination of threshold strategy of Birge-Massart and Normal Shrink method for modeling of detail sub-band coefficients. The implemented investigation and obtained results by using real NB images attempt to make diagnostic more obvious. The proposed technique can be helpful for detection and classification of superficial neoplastic lesions.

REFERENCES


