X-Ray Images Enhancement using Human Visual System Model Properties and Adaptive Filters

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ABSTRACT This paper proposes the use of an adaptive image enhancement system that implements the human visual (HVS) properties for the contrast enhancement of the X-Ray images. X-Ray images are of poor quality and usually interpreted visually. The HVS properties considered are the adaptive nature, multichannel, the highly non-linearity. The proposed method is adaptive, nonlinear, multichannel, and combins adaptive filters and homomorphic processing. Results presented illustrate the effectiveness of the proposed method.

I- Introduction

Chest and other X-ray radiography still the most common methods of radiological examinations and methods of detection of some diseases, such as cancer [1]. The HVS is usually used for visualizing and analyzing X-Ray image. A reasonable conclusion is that it is adaptive in nature and the sensing of the retinal image intensities and transducing them into neural correlates is highly non-linear [2,9,10]. The HVS is also a multichannel mechanism, where it contains a number of parallel channels (filtering mechanisms), each selective to a limited range of image spatial frequencies. The HVS can play a role in the enhancement of X-Ray image for display. For example, concerning the edges in the image, the retina acts to extract and emphasize the edges from the scene by subtracting the low spatial frequency variations and by amplifying the resulting signal to fill the dynamic range of the optical nerve. This technique is usually called the use of unsharp masking [2,3]. An image enhancement technique that exploits the spatial frequency qualities of an image is that of the homomorphic image processing [4]. The image vision model used in this paper is simply the log in combination with the adaptive system, but it suffices to enhance the quality of interest. In [3], they provided a method of image contrast enhancement, based on processing in homomorphic domain, using a combination of fixed HP and fixed LP filters, as shown in figure (1). We will call this system as single fixed HF channel system. The use of adaptive filters which changes characteristics according to the changes in the image statistics in combination with homomorphic processing coincides with the HVS model properties explained before. The Two-dimensional Least mean square (TDLMS) filter algorithm, presented in [8] is a method to find an approximate solution for the optimum Wiener-Hopf equation [5-7]. Adding some simple constraints on the coefficients of the weight matrix, the filter changes characteristics to an adaptive High Pass Filter or to an adaptive Laplacian operator [7]. Any other method of adaptive filters is also applicable. This paper, also, proposes a new contrast enhancement method with **multiple HP channels,** in both spatial and homomorphic domains.

The paper is organised as follows. In section II, the method of image contrast enhancement is explained. In section III, a new contrast enhancement method with multiple HP channels is presented. Section IV presents method of spatial domain enhancement. In section V we propose a method of adapting the enhancement parameters according to the image local contrast. Application results performed are in section VI. Finally conclusions are given in section VII.

II-Contrast Enhancement using Homomorphic Transformation

The penetrating nature of X-rays, nonlinear sensor, and the absorption and scatter phenomena associated with X-rays are energy dependent and complicates any subsequent processing. The resulted image is also nonstationary in the mean and in the variance which suggests the use of adaptive filters to efficiently deal with these images. Simplest image model in the homomorphic processing technique assumes that the radiance from the scene is the product of a low spatial frequency illumination component and a high spatial frequency reflectance component from the objects in the scene [3]. Adopting this image model to X-ray images, then, the ideal undegraded image $f(m,n)$ can be represented as:

$$f(m,n) = r(m,n)\ i(m,n) \qquad (1)$$

where $i(m,n)$ which represents the illumination which can be seen as equivalent to the intensity of the incident X-ray energy passed to the film while $r(m,n)$ represents the reflectance or equivalently represents the change in body absorption of the penetrating X-ray energy. *i(m,n)* is assumed to be the primary contributor to the dynamic range of an image. It is assumed to vary very slowly. While the reflectance *r(m,n)* that represents the details of an object and is assumed to be the primary contributor to local contrast. It is assumed to contain the spatial activities and vary very rapidly. To separate *i(m,n)* from *r(m,n)*, logarithmic operation is applied to equation (1), which results :

$$\log(f(m,n)) = \log i(m,n) + \log r(m,n) \quad (2)$$

If we assume that log *i(m,n)* remains slowly varying and log *r(m,n)* remains rapidly varying, low pass filter of log *f(m,n)* will result in log *i(m,n)* and high pass filtering of log *f(m,n)* will result in log *r(m,n)*.
In homomorphic processing, as shown in figure 1, the X-ray image is first log transformed, is then sent through a spatial filter which suppresses the *i(m,n)* component and enhances the *r(m,n)* component, and is finally exponentially transformed back into the intensity (space) domain. The resulting displayed image has its contrast subjectively enhanced. In this paper the homomorphic transformation are applied to images digitised to 256 grey levels. Considering *f* as the numerically quantised value of the grey levels where $0<f(m,n) < 255$. Hpmomorphic transformation is applied as :

$$g(f(m,n)) = \log(f(m,n)+1) \quad (3)$$

The output of the enhancement filter is obtained as:

$$\hat{g}(f(m,n)) = a\ (H_{LP}\{g(f(m,n))\}) + b\ (H_{HP}\{g(f(m,n))\}) \quad (4)$$

Where α and β are the contrast enhancement parameters and α< 1 and β>1. H_{LP} { } is the LP filtering operation either fixed or adaptive, and H_{HP} { } is the fixed or adaptive HP operation. The corresponding inverse transformation that is to be applied after processing is :

$$\hat{f}(m,n) = 10^{\hat{g}(f(m,n))} \quad (5)$$

where $\hat{f}(m,n)$ is the enhanced output image. This technique is expected to be successful because it exploits the same type of enhancement occur in the retina.

III- Multiple HP channels for contrast enhancement

The applications show that the size of the HP filter affects the final output image. In this section we propose a method that considers and enhances all the high frequency range and reduces noise amplification as a result of the effect of smaller window size and reduces the blurring effect of larger window sizes. In this method, as illustrated in figure (2), we utilize three different channels with three HP filters with different filter sizes. The smallest size filter is used to enhance the very high frequency image information (small details). This filter is expected to increase the noise in the resulted output image. The medium size filter is used to enhance the medium HF image information (medium details), while the large size filter is used to improve and restore image details. The system can also be implemented in spatial and Homomorphic domains. The results of the three HP filters are linearly combined as follows to obtain the enhanced output image.

$$\begin{aligned}\hat{g}(f(m,n)) = {} & (a_{HPL} + a_{HPM} + a_{HPH})(H_{LP}\{g(f(m,n))\}) + \\ & b_{HPL}(H_{HPL}\{g(f(m,n))\}) + \\ & b_{HPM}(H_{HPM}\{g(f(m,n))\} + \\ & b_{HPH}(H_{HPH}\{g(f(m,n))\}\end{aligned} \quad (6)$$

The output is then calculated as:

$$\hat{f}(m,n) = 10^{\frac{\hat{g}(f(m,n))}{3.0}} \quad (7)$$

where H_{LP} is the low pass filter output and H_{HPH} is the output of the small size HPF and β_H in the scale factor of the small size filter. H_{HPM} is the HP output of the medium size filter and β_M is the scale factor, H_{HPL} is the HP output of the large size filter and β_L is the scale factor.

IV- Spatial domain Single HP channel contrast enhancement

The method explained in the section II can be implemented in spatial domain (without log transformation). Assuming adaptive filters as explained in section II, the method will be implemented in spatial domain where the output of the contrast enhancement filter is obtained as:

$$\hat{f} = r(m,n)^{b} \quad i(m,n)^{a} \quad (8)$$

where *r(m,n)* is the reflectance image component and is the output of the HPF, and *i(m,n)* is the illumination component of the image and is the output of the LPF.

V- Adapting contrast enhancement parameters α and β to image contrast

The values of the scaling parameters α and β are adaptively adjusted according to the image local contrast as follows: assuming the local average of pixels in the local neighborhood of the processed pixel of size NxN in the log domain is S_{av}, then α can be expressed as:

$$a = \frac{\log(255)}{(\log(255) + S_{av})}, b = 1.0 + w(a - 0.5) \quad (9)$$

For the proposed spatial domain enhancement method, the parameter α is calculated as:

$$a = 255/(255 + S_{av}) \quad (10)$$

VI- Results:

The adaptive contrast enhancement techniques are applied to a number of images. Figure 3 shows the results of using the contrast enhancement methods. The original [8] used are shown in figure 3-a. The image in figures 3-b shows the result of applying the (single fixed HP channel) method in [3] using fixed 3x3 LP averaging filter and HPF mask when the images processed in homomorphic domain. The result of proposed method using adaptive filters in single HP channel is shown in figures 3-c. The image in figure 3-d shows the result of the proposed multiple HP channels method. The image in figures 3-e shows the result of the proposed spatial domain single HP channel method. Figure 3-f shows the result of using Wallis method in [8] and 3x3 filter. The results illustrate that the proposed methods using single HP channel produces better enhancement and less noise amplification than the method of fixed filters in [3]. In addition, the amount of enhancement is controlled by the elements in the adaptive HPF and the value of the adaptive enhancement parameters α and β. The images in figure 3-d of the multiple HP channels method when compared to other method illustrate that the multiple channel method produces better enhancement and without any noise amplification. The spatial domain method results are very good and the method is equivalent to the homomorphic single channel method without the need to log transformation.

VII- Conclusion:

X-ray Chest and other X-ray radiography are the most common methods of radiological examinations and detection of some diseases, such as cancer. These images are of poor quality and usually interpreted visually. The HVS behavior which is adaptive in nature, multichannel, and is highly non-linear, must be considered. The proposed technique considers the properties of the HVS model. The adaptive filters change characteristics according to the changes in the image. The system is nonlinear through the use of homomorphic processing and the adaptation of contrast enhancement parameters α and β to the changes in the input image local characteristics and contrast. This method of adaptive parameters calculation controls the enhancement locally. The system is multichannel through the use of multiple HP channels with different HP filter sizes. The HP filters with large sizes, and the averaging of the three outputs of the three HP channels, causes great noise reduction in the output image.

The method of multiple HP channels is shown to be very simple, effective and avoids the noise amplification and details blurring. In addition to the advantages explained before, the adaptive method does not assume any knowledge about the image statistics or characteristics. Our conclusions are that the methods of image enhancement using adaptive filters are very useful and outperform fixed filter methods.

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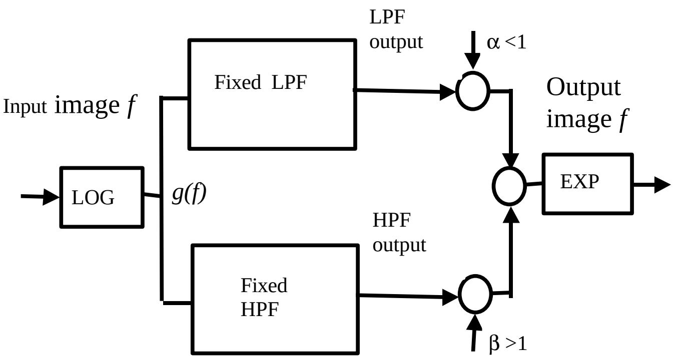


Figure 1 Single HP channel and fixed filters image enhancement

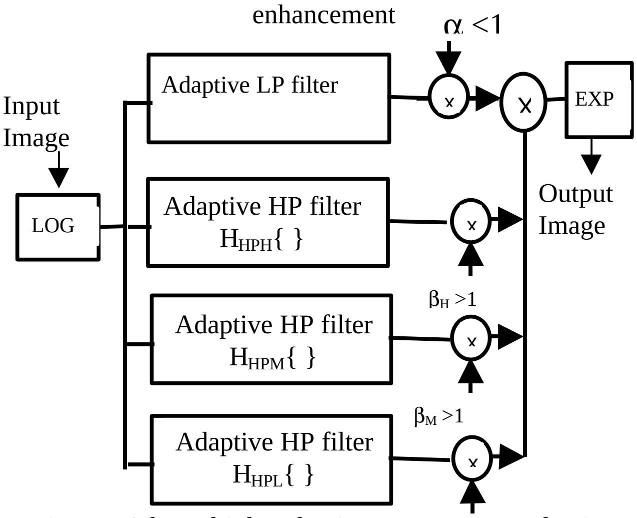
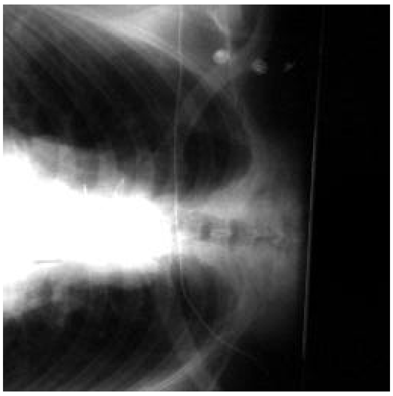
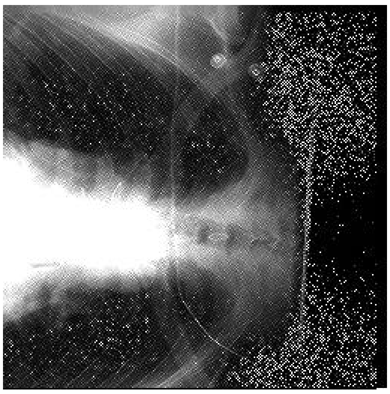


Figure 2-b multiple adaptive HP adaptive contrast enhancement



(A)



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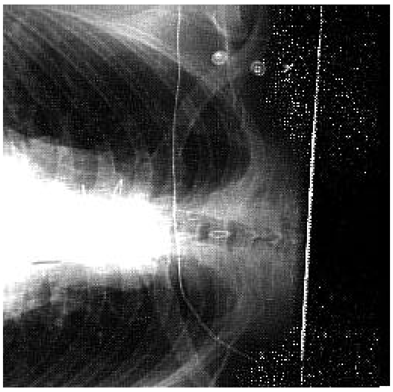

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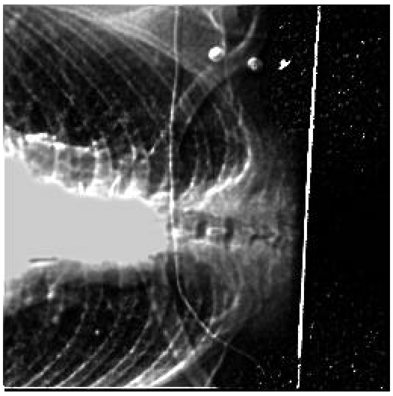

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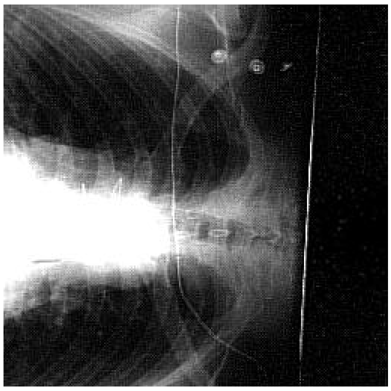

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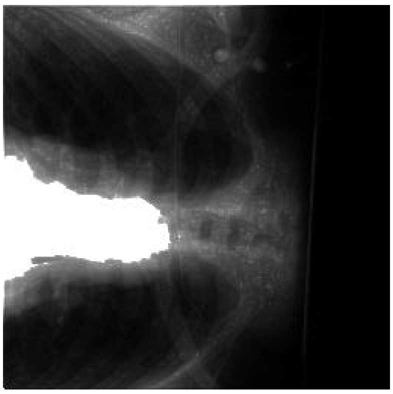

(F)

Figure (4), X-ray Ribs image contrast enhancement (A) original, (B) fixed filters enhancement in [4] (C) Single HP channel adaptive filters, (D) three HP channel adaptive filters (E) spatial domain method in section VI. (F) The output using Wallis method [8].