

A Wavelet Based GUI for NM Images Filtering Using Variance-Stabilizing Transformation

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Abstract – In this paper we present an application and its interface for pre-processing of chest region NM images. It works in the Matlab environment and uses Matlab user defined functions. The software processes the images in the discrete wavelet transform domain. It uses QMF filters with linear phase designed to achieve both good image decomposition and near perfect reconstruction. Due to the fact that the noise in NM images is highly dependent on the image space distribution and signal intensity, it applies the Anscombe variance-stabilizing transformation over original images. As a result, the transformed images are characterized with a white Gaussian noise model and Donoho's level dependent threshold is used.

Keywords – Nuclear medicine image, wavelet-domain filtering, autocorrelation, denoising.

I. INTRODUCTION

Nuclear Medicine (NM) images are diagnostic digital images, which provide both anatomical and functional information about a patient. They represent the projection of the distribution of the radioisotopes in the patient body after injection of certain dose of radioisotopes. The raw NM images are based directly on the total number of photon counts detected over fixed observation period by computerized gamma cameras. They are very noisy due to the nature of the gamma ray emission process and the operational characteristics of the gamma cameras (low count levels, scatter, attenuation, and electronic noises in the detector/camera). The noise is highly dependent on the image space distribution and signal intensity. Therefore, a suitable image pre-processing must precede the NM images analysis in order to provide an accurate recognition of the anatomical data of the patient (the boundaries of the various objects – organs). This process of separating signal from noise is a rather difficult and much diversified task that should be adjusted to the organs and tissues, which physiology is to be investigated.

This paper presents an application and its graphic user interface (GUI) for pre-processing of chest-region NM images. It reduces the noise in the discrete wavelet domain. The images are decomposed with QMF filters with linear phase. The filters are designed to achieve both good image decomposition and near perfect reconstruction. Due to the signal-dependence of the noise, the Anscombe variance-stabilizing transformation is applied over the original images. As a result, the transformed images are characterized with a white Gaussian noise model and Donoho's level dependent threshold is used.

The paper is organized as follows. The software for processing NM images and its GUI are shown in the Section II. The Section III discloses the algorithm that is utilized by the software. Ideas for improving the efficiency of the software are considered in the Section IV, while the Section V concludes the paper.

II. THE GUI FOR PROCESSING NM IMAGES

The Fig. 1 shows the GUI we have developed for processing the NM images. It works in the Matlab environment and uses Matlab user defined functions. It can be used both for displaying raw images and processed images.

The main window on its left side contains two frames (labels 1 and 2 in Fig. 1) where the raw image and the processed image are displayed. By clicking the GUI button 'OPEN IMAGE' (4) a dialog window appears and user can choose a file that has the Matlab extension 'mat'. The set of images that are contained in the selected mat file is shown in the top-right part of the GUI (6). An image selected from this set appears in the top-left frame (1). By clicking the button 'FILTER' (5) this image is processed and the result is shown in the bottom-left frame (2). It is possible to remove the shadow around the object by moving the slider or typing a value in the adequate textbox (8). In addition, the user can choose a colormap from the combobox (7) with a list of defined Matlab colormaps (Fig. 3).

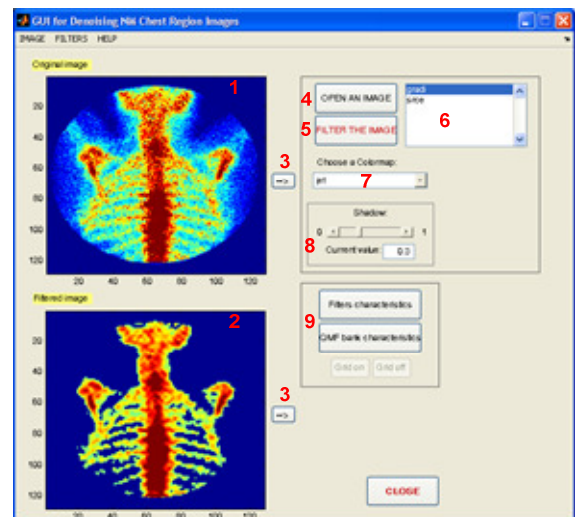


Fig. 1 The main window

1. Top-left frame for the original image; 2. Bottom-left frame for the result; 3. Buttons for exporting the images; 4. Button for reading an image; 5. Button for filtering; 6. The images that are contained in the selected 'mat' file; 7. Colormap combo box; 8. Slider for removing the shadow; 9. QMF bank and filter characteristics

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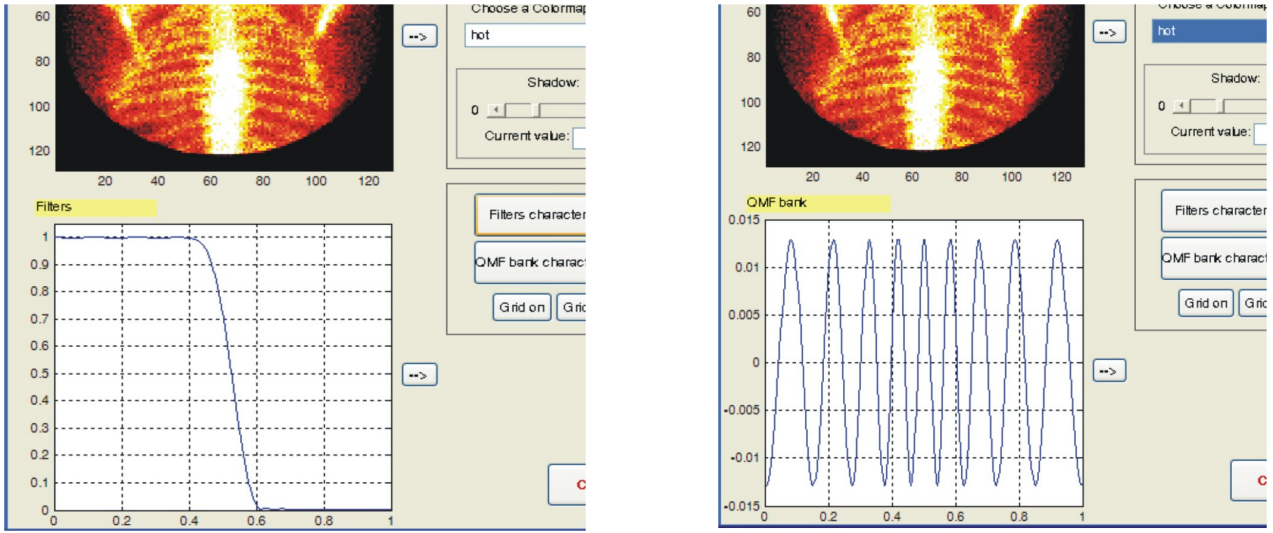


Fig. 2. The QMF bank and prototype filter characteristics

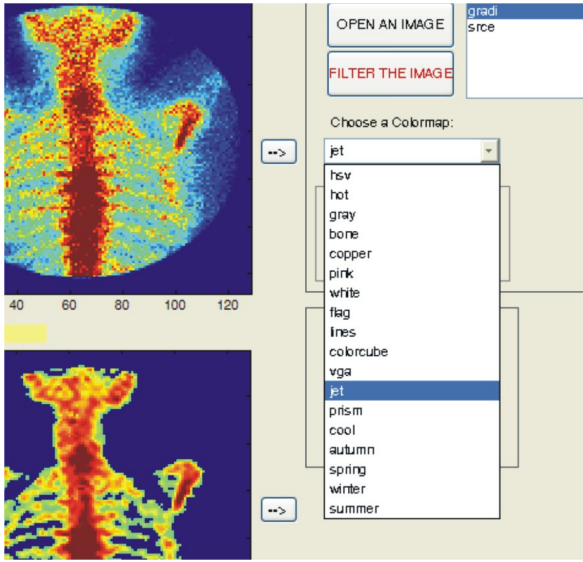


Fig. 3. Choosing a colormap

By clicking the GUI buttons labelled ‘FILTER CHARACTERISTICS’ or ‘QMF BANK CHARACTERISTICS’ (9), the prototype filter characteristics or QMF bank characteristics appear in the bottom-left frame for results, respectively. This is shown in Fig. 2. By clicking the buttons labelled with arrow (3), the images are exported in a separated window for further processing or using in the Matlab command window or other application.

III. THE ALGORITHM THAT WORKS BEHIND

Chest region images contain quantum noise, which is highly dependent on the underlying light intensity pattern being imaged. For denoising purposes, it is often advantageous instead of working in the spatial (pixel) domain to work in a transform domain. One possible choice for image transform is the discrete wavelet transform (DWT) domain.

The Discrete Wavelet Transform (DWT) decomposes a signal into a set of orthogonal components describing the signal variation across the scale [1]. The orthogonal components are generated by dilations and translations of a prototype function ψ called *mother wavelet*.

$$\psi_{i,k}(t) = 2^{-i/2} \psi(t/2^i - k), \quad k, i \in \mathbb{Z} \quad (1)$$

In analogy with other function expansions, a function f may be written for each discrete coordinate t as sum of a wavelet expansion up to certain scale J plus a residual term, that is:

$$f(t) = \sum_{j=1}^J \sum_{k=1}^{2^{j-1}M} d_{jk} \psi_{jk}(t) + \sum_{k=1}^{2^{J-1}M} c_{Jk} \phi_{Jk}(t) \quad (2)$$

Motivated by the DWT tendency to concentrate the energy of a signal into a small number of coefficients, while a large number of coefficients have low SNR, we modify the wavelet coefficients w_i according to:

$$\hat{w}_i = w_i \cdot h_i \quad (5)$$

where the shrinkage filter h_i corresponds to the “soft threshold” nonlinearity

$$h_i(\text{soft}) = \begin{cases} 1 - \frac{\tau \text{sgn}(w_i)}{w_i}, & \text{if } |w_i| \geq \tau \\ 0, & \text{if } |w_i| < \tau \end{cases} \quad (7)$$

with τ a user-specified threshold level.

But, because the noise in the NM images is not additive white Gaussian, the noise level is not uniform throughout the image and hence uniform across all the wavelet coefficients. Therefore, a simple global noise threshold can not be determined independently on the signal and the wavelet-domain filtering based on a global threshold is inappropriate. Hence, for denoising this type of images we use the Anscombe (1948) variance-stabilizing transformation:

$$y_{i_1, i_2} = \sqrt{N_{i_1, i_2}} \quad (8)$$

As a result, the coefficients of the transformed images are characterized with a white Gaussian noise model [2] and we calculate the Donoho's level dependent threshold:

$$\tau_j = \sigma \sqrt{2 \log N} \cdot 2^{(j-J)/2}, \quad j = 0, \dots, J \quad (9)$$

where σ is the noise standard deviation (to be estimated), J is the number of decomposition levels, j is the scale level and N is the total number of image pixels [2].

In addition, by applying nonlinear filtering to the wavelet coefficients, we discard the wavelet coefficients with a low SNR. Therefore the signal perfect reconstruction (PR) is not possible. Hence we decompose the images by using a near perfect reconstruction (NPR) QMF bank instead of using standard wavelet filters. With this we provide better frequency response and increase the design flexibility since the filter cut-off frequency, filter length and overall reconstruction error of the designed QMF bank are design parameters which has to be adjusted to each image. Software can display the prototype filter and QMF bank characteristics when buttons labelled with 9 in the GUI (Fig. 1) are clicked. In the algorithm the prototype filter is designed according to the method proposed in [3]

The whole algorithm utilized by the software is completely described in [5].

IV. FUTURE WORK

NM images are a specific kind of images and a process of separating signal from noise is a difficult task. In this Section we consider our future work to improve the efficiency of the software.

A NPR-QMF bank allows certain flexibility in the designing of its filters. So, the prototype filter cut-off frequency as a design parameter can be chosen taking into consideration the images 2D power spectrum characteristics [6]. The power spectrum of all the chest region NM images is concentrated on low frequencies in an ellipse like region. This means, the filter cut-off frequency always can be chosen such, so the images can be decomposed in one level only.

Further, the software can be upgraded to be able to process a set of dynamic NM images [4]. Since the dynamic images are consecutive, it can be expected that each image contains certain information that can be used for further pre-processing of its time neighbouring images [7]. This information is contained in the vectors formed by joining all the pixels from

all the images that are located at same position. The vectors have a length equal to the total number of images in the images set. The vectors obtained from real NM images form a shape that contains isolated peaks as a result of the noise presence in the images.

In addition, the threshold for filtering the wavelet coefficients can be adjusted to the signal intensity since the noise is signal dependent. This means, instead using a global threshold, the bigger signal intensity the bigger threshold and vice versa.

V. CONCLUSION

We present a GUI for pre-processing chest region NM images. It works in the Matlab environment and uses Matlab user defined functions. The software processes the images in the DWT domain by using NPR-QMF filters with linear phase. The Anscombe variance-stabilizing transformation is applied over original images and as a result the transformed images are characterized with a white Gaussian noise model and Donoho's level dependent threshold is used.

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