ON THE RADIONUCLIDE MOVEMENT DEPENDENT FILTERING ON NUCLEAR MEDICINE IMAGES

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Abstract: In this paper we present our approach on pre-processing chest region dynamical NM images which enables anatomical data extraction of the vena cava and the heart. The aim of the method is developing sophisticated diagnostic software that could automatically offer the optimal positions and the shapes of the regions of interest needed for the heart studies.

Keywords: Nuclear medical image, median filtering, autocorrelation, denoising.

1 Introduction

Nuclear Medicine (NM) images are diagnostic digital images, which provide both anatomical and functional information. They present the projection of distribution of radioisotope(s) in a body of a patient after injection of adequate dose of radioisotope(s). The raw NM images are based directly on the total counts detected over a fixed observation period by computerized gamma cameras and have a low signal-to-noise ratio (SNR). Therefore, a certain image pre-processing must precede the NM images analysis, which should provide an accurate recognition of anatomic data of the patient.

The conventional way of extracting anatomical information from NM images is by summing up a certain number of sequential raw images. In many occurrences, this approach gives sufficiently good results, but in some situations, the objects in the resultant image appear enlarged and deformed.

The paper considers pre-processing of dynamical chest-region NM images, captured immediately after injection of the radioactive material into the vein of a patient. A combination of median filtering technique and radionuclide spreading direction adaptive filtering is used. An analysis of the radionuclide movement is carried out and each image is filtered in a direction that depends on the direction of the radionuclide movement at that moment.

The paper is organized as follows: Section 2 shows the creating process of the dynamical NM images, and formulates the problems due which raw NM images should be pre-processed. In Section 3, we propose our approach for extracting the boundaries of the anatomical data in the chest region from a set of raw sequential images. Section

4 outlines the adaptive filtering. Section 5 demonstrates the performance of the proposed approach applied on a set of real NM images captured with our own upgrading gamma camera system. The conclusion and future research are discussed in Section 6.

The effectiveness of the proposed method is investigated on real NM images recorded and processed by our own gamma camera upgraded system, developed at the department of NM in Bitola. The results indicate that this approach outperforms classical filtering in terms of developing sophisticated diagnostic software that could automatically offer the optimal positions and shapes of the regions of interest needed for the heart study.

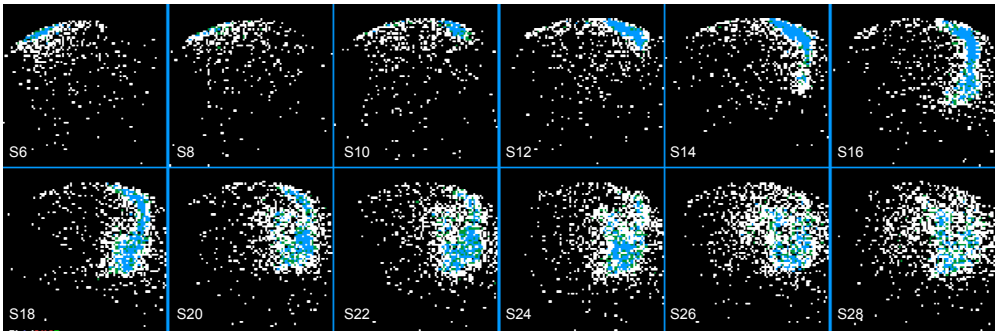

Fig. 1: Sequence of enhanced noised images (τ=0.4 s)

2 NM image creation process

The process of generating the NM images starts after injecting a small dose of radioactive material (for safety reasons) with a total quantity of

$$Q = \int_0^T q(t)dt \qquad (1)$$

where $q(t)$ is an injection flow of the radionuclide and T is the total injection time. The injected radionuclide spreads and generates some space and time varying the *radionuclide density function* (r.d.f.), $\rho(x, y, z, t) \geq 0$, into the body of the patient ($t > 0$; $x, y, z \in B$, (B – body of the patient)).

After injecting radioactive material in the patient (right hand) vein, the blood-radioactivity mixture passes through the heart and lungs, returns to the heart and proceeds with spreading through each cell of the patient's body through its arteries. This process could be recorded as a set of N NM images (Fig. 1):

$$S_k^r(i,j,t_k,\tau), \qquad k = 1,2,...,N \qquad (2)$$

where r (power of 2, $r \in \{2^5, 2^6, 2^7, 2^8\}$) is the image resolution index; $i, j = 1,2,...,r$ are indexes of the image matrix that corresponds to a set of $r \times r$ imaginary rectangular

cells of the gamma camera detector plane; t_k is the beginning of generating the image; τ is the accumulation time.

Each image $S_k^r(i,j,t_k,\tau)$ (in further text $S_k^r(t_k,\tau)$ or S_k^r) is created with counting the detected gamma rays in the cells of the image matrix in the interval $[t_k, t_{k+1}]$ ($t_{k+1} = t_k+\tau$; $k = 1, 2, \ldots N$; $t_1 = 0$). This type of images usually has very short accumulation time ($\tau \leq 0.5$) in order to record fast spreading of the radionuclide. Therefore, the accumulated energy (counts) per image is very small. In addition, the images captured with a higher resolution have a relatively lower level of image dynamics defined by

$$d_k^r = \max_{i,j}(S_k^r(i,j)) - \min_{i,j}(S_k^r(i,j)) \qquad (3)$$

Since the lowest pixel intensity is 0 for this type of NM images, the image dynamics is defined by

$$d_k^r = \max_{i,j}(S_k^r(i,j)) \qquad (4)$$

Each NM image contains a rather high level of noise caused by: a) combining the radionuclide with the blood and spreading of this mixture, b) hydrodynamic processes in the blood vessels because of pumping work of the heart and c) randomness of the gamma rays emission and rays detection by the gamma camera.

Taking this into considering, the raw images should be adequately pre-processed in order to extract the anatomical information about the position of the vena cava superior and the heart.

3 Images processing

The process of spreading of the radionuclide can be divided into three consecutive phases [3]. The first phase begins with the injection of the radionuclide and ends when the radionuclide comes to the heart; the second one begins when it enters into the heart and proceeds further towards the lungs, and the third one begins when the radionuclide starts returning to the heart. Breakpoints between the phases can be determined accurately from the functions of some image features (image dynamics, covering surface with nonzero intensity pixels) as described in [3].

Images recorded in the first phase show spreading of rather compact mass of the radionuclide only through the vena. In spite of that, these images contain a high level of spatially distributed noise in a form of isolated pixels in the neighborhood of the vein.

Both the vein and the heart can be recognized in the images recorded at the beginning of the second phase. Later, the vein disappears and only the heart remains. The projection of the heart in this phase is the best, but its boundaries remain poorly shaped due to the lower concentration of the radionuclide in the heart. In addition, the heart pulsation causes some degrading effects to the shape of the heart. Consequently, the classical filtering techniques cannot be successfully applied to the whole image.

In our approach, we divide the set of all NM images in two subsets: subset of images where only the vein appears (I phase) and subset of images where the vein and the heart appear together (II phase). Then, we remove the vein segment from the images of the second subset, and decrease their resolution by half in order to reduce the degradation. We apply a combination of median filtering and a radionuclide movement depended filtering to all the images from the first subset and the remaining heart segment in the images from the second subset. An analysis of the radionuclide movement is carried out and each image is filtered in a direction that is normal to the direction of the radionuclide movement at that moment. The algorithm is presented in Fig. 2.

Since the dynamical images are consecutive, it can be expected that the successor and predecessor of each image S_k contain certain information about it. In order to include this part of information we use the following formula:

$$S_{ke}(i,j) = \max_{i,j}\{S'_{k-1}(i,j),\ S_k(i,j),\ S'_{k+1}(i,j)\}\ 1 \le i,j \le r;\ k = 1,2,\ldots,N \quad (5)$$

where $S'_k = \psi(S_k)$, and $\psi(\cdot)$ is an image processing function that corresponds to the aforementioned algorithm (Fig. 2). The same processing techniques are applied to each image, S_{ke}, $k = 1, 2, \ldots, N$ (Fig. 2, Eq. 5).

We compose a resultant image by superposition of the high-energy sub-images of S_{ke}, ($k = 1,2,\ldots,N$), obtained by discarding those pixels of S_{ke}, which intensity is below certain threshold (say $0.8 \cdot d_k$).

The block diagram of the algorithm for anatomical data extraction is presented in Fig. 3.

4 The adaptive filtering

An analysis of the radionuclide movement is carried out and each image is filtered in a direction that depends on the direction of the radionuclide movement at that moment. First, we identify the radionuclide spreading direction in the each image (2-D FFT is carried out). Next, we rotate the specific image for the adequate angle θ, obtained in the previous step and obtain an image where the radionuclide spreads in horizontal direction. Low-pass FIR filtering is applied to the image in vertical direction. The filtrated image is rotated for an angle θ. This is shown in Fig. 4.

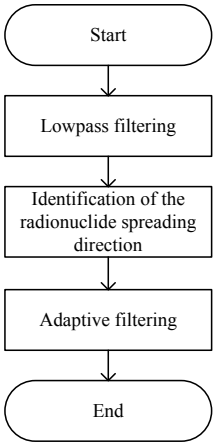

Fig 2: Processing algorithm

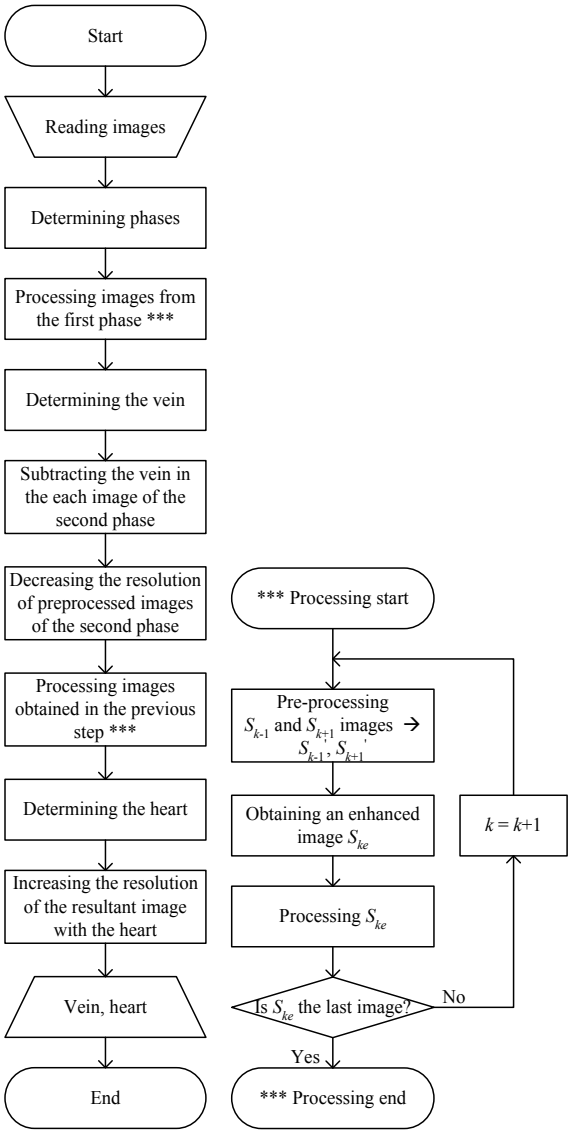

Fig 3: Anatomical data extraction algorithm

5 Experimental results

In this Section, we illustrate the effects of our method and compare them with the results obtained by using the conventional approach. Both methods were applied on a same subset of 24 sequential dynamic NM images from the phases I and II, recorded with a resolution of 128x128 and accumulation time τ=0.4 [s].

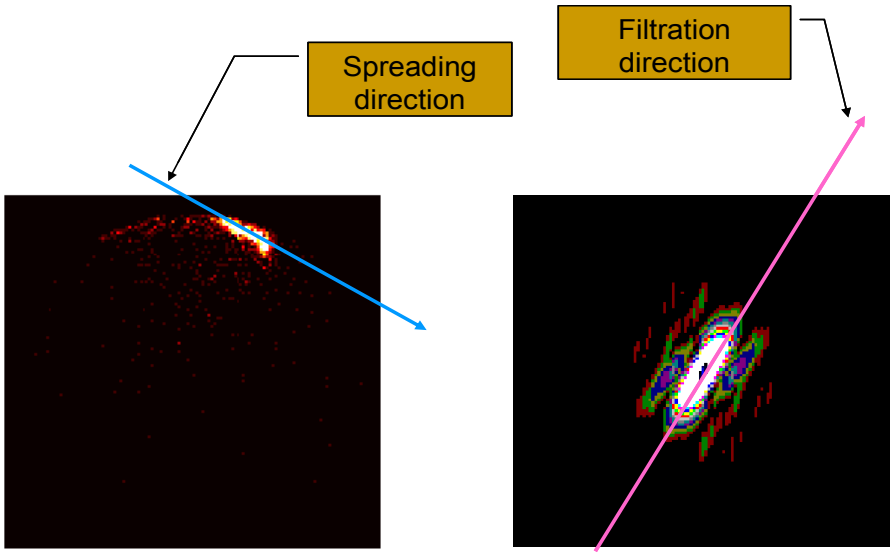

Fig. 4: a) Raw NM image b) 2-D FFT of the image in a)

The final effect of the proposed method is presented in Fig. 6, while the effect of the conventional approach is presented in Fig. 5. The boundaries of the heart in Fig. 6 are reduced due to the small number of the used NM images from the second phase. This image has sharp edges of the vein and the heart, while the image in Fig. 5 contains relatively high level of noise that blurs the edges of these objects. Therefore, the image in Fig. 6 is more suitable for an upgrading expert system that could provide automatic identification of optimal shapes and positions of regions of interest needed for further physiological diagnostics.

The quality of the image in Fig. 5 could be further improved by using certain low pass filtering techniques, but the projections of the vein and the heart would still suffer from certain deformations. These deformations could degrade the effects of an expert system for automatic identification of the optimal positions and shapes of regions of interest needed for further investigations.

6 Conclusion

The presented approach offers automatic extracting of the anatomic data from the chest region dynamical NM images. The aim of this approach is to determine anatomical data in order to upgrade the software with an expert system that could identify the optimal positions and shapes of the regions of interest needed for the heart study. We demonstrate the performance of the proposed method on real dynamical NM images, recorded and processed by our own upgraded gamma camera system developed at the department of NM in Bitola.

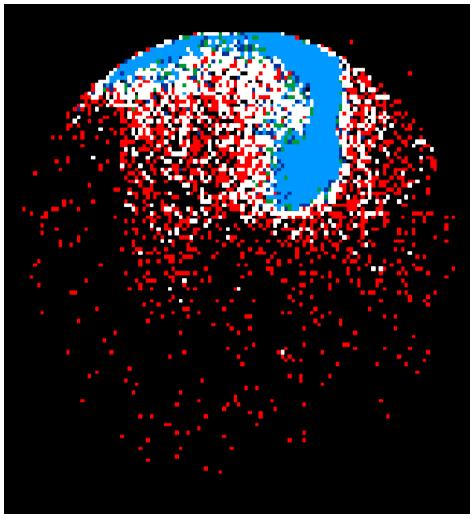

Fig. 5: The resultant image obtained by using the conventional way

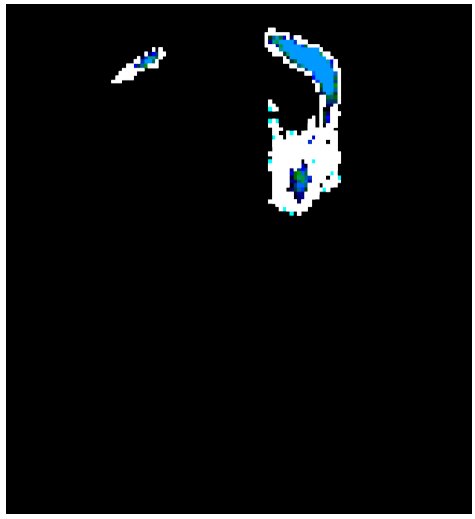

Fig. 6:The resultant image obtained by using the proposed approach

7 References

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