A Method for Automatic Heart Localization form Thoracic SPECT Planar Images

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***Abstract*— In this paper we propose a method for automatic localization of heart from Single Photon Emission Computed Tomography (SPECT) planar images. The proposed algorithm consists of three steps. The first step is to isolate the best Left Anterior Oblique (LAO) slice from the projection data set. The isolated slice is cropped into 2/3 from the vertical side. This operation eliminates the abdominal structure such as the liver. The second step in the process is to detect edges, which is performed in an iterative manner. The final step is to find the doughnut shaped left ventricle on the edge image using a pattern matching algorithm. Based on the localization of heart, we can set the reconstruction limits for the projection dataset. The proposed method is a fully automatic one and is tested with 54 test images with a success rate of 100%.**

***Index Terms*— Edge Detection, Heart localization, SPECT and Thoracic planar images.**

I. Introduction

Single Photon Emission Computed Tomography (SPECT) is an important nuclear medicine modality and has been extensively used in cardiac nuclear imaging [1] – [3]. This noninvasive imaging technique permits evaluation of patients with suspected or known coronary artery disease [3]. The projection image, the most basic building block in the SPECT, consists of a 2-dimensional snapshot of the 3-dimensional distribution of radioactivity in an underlying patient and is obtained by positioning a scintillation detector with its plane parallel to the patient's long axis [4]. SPECT imaging is based on the reconstruction of tomographic images from 2D projection images. In this paper we propose a method for automatic selection of reconstruction limits for the reconstruction of cardiac image from the thorax data. The reasons for limiting the reconstruction area are twofold. First, doing so reduces the amount of data processed and the digital storage space required. Secondly, discarding part of the projection image volume permits elimination of abdominal structures, such as the liver and the intestines, which often contain high activity and therefore reduce visibility and full use of the grey/color scale by the myocardium [4] [5].

Myocardial perfusion SPECT processing consists of a number of steps and is generally performed by a technologist with specific experience on the computer platform where the data resides. Here first the technologist scrolls through the projection image set and selects an image (a left anterior oblique projection, usually LAO 45^0) where the left ventricular (LV) myocardium is most visible. Full automation of myocardial perfusion SPECT processing is desirable for a number of reasons. Most notably, the reproducibility of a task performed by an automated algorithm is superior to that of a human operator; thus automated processing obviates the problem of intraobserver variability. To the extent that processing rules exist, can be clearly identified and are incorporated into the algorithm, automation will also yield more accurate results, by consistently applying those rules in its analysis. Incorrect processing however will create artifacts that can be reflected in the quantitative program output, creating the perception that quantification itself is a fault and hampering rather than helping diagnosis. Finally, automation saves time and increases efficiency, partly because the operator's manual tasks are performed more rapidly and because the operator is no longer required to continuously monitor processing, waiting for his/her time to intervene [4] [5].

II. Materials and Methods

The proposed method for automatic determination of reconstruction limits consists of three steps. The first step is to isolate the best LAO slice from the set of SPECT planar images. The isolated slice is cropped into 2/3 from the vertical side. This operation eliminates the abdominal structure such as liver and intestines, which often contain high activity. The step is the detection of edges, which is performed in an iterative manner. The last step is to extract the doughnut shape structure (which is greater than 8 pixel and not less than 22 pixels diameter) from the edge image using a pattern-matching algorithm.

Determination of Best LAO Slice

The method starts by extracting the best LAO slice from the projection volume image. The selection depends on the SPECT planar imaging protocols like positioning of the patient, number of gamma camera detectors, start angle of the camera head, scan arc length, step angle of the camera head and rotation direction. We derived a simple formula to find out the best LAO view slice based on the above-mentioned SPECT planar imaging protocol. The formula is given below,

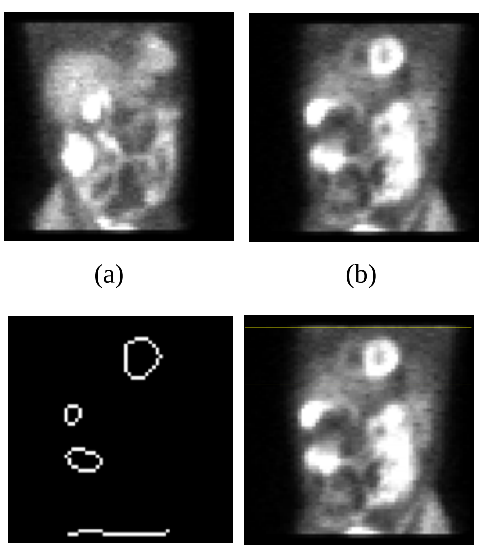
$$BLAO = \left(\left| SA - 135^{\circ} \right| / AS \right) * No.of\ Slot \qquad (1)$$

where,
BLAO – Best Left Anterior Oblique
SA – Start Angle of the gamma camera head
AS – Angular Step

If the SPECT image is gated tomo then Number of Slots = 8 or 16 else it is always 1. After the determination of BLAO slice, it is cropped into 2/3 from the vertical side of the slice.

Edge Detection and Pattern Matching

In the thoracic SPECT planar images (at BLAO slice) the Left Ventricular (LV) myocardium seems like donut shaped structure (shown in fig. 3 LAO view). Here we used canny edge detection algorithm to extract the circular shaped component (with varying threshold values). The basic idea of the canny edge detection is to detect the zero-crossing of the second directional derivative of the smoothed image in the direction of the gradient where the gradient magnitude of the smoothed image being greater than some threshold depending on image statistics [6]. So, a constant threshold may not fit for all type of images. The edge detector generates a strong edge in the donut shaped area, such as LV myocardium, producing a circular like structure as shown in the Fig. 1 (c). The algorithm is explained in the below flow chart.



(a) (b) (C) (D)

Fig. 1. Automatic localization of LV myocardium, (a) First slice of the volume data, (b) BLAO slice, (c) edge image and (d) reconstruction limits marked by yellow lines

Algorithm:

1. Read the planar volume image.
2. Collect the required header informations, such as, start angle, angular step, scan arc, etc,.
3. Obtain the BLAO slice using the eqn. (1).
4. Crop the BLAO slice by 2/3 of size from the vertical side.
5. Set the initial threshold value as 0.65 for edge detection algorithm.
6. Perform the Canny edge detection algorithm.
7. Search the circle with size less than 8 pixels and not exceeding 22 pixels.
8. If step 7 is not satisfied; the threshold value is decreased by 0.05 and steps 6 & 7 are repeated
9. Finally, set the reconstruction limit to 4 pixels above and below from the circle along the vertical direction.

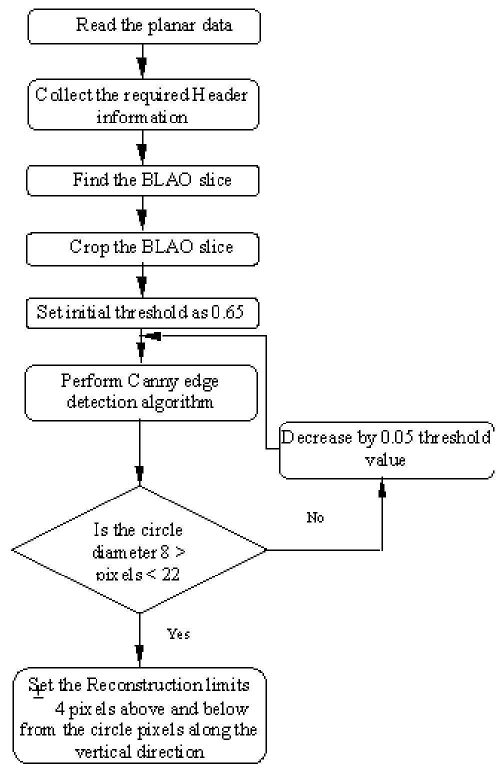
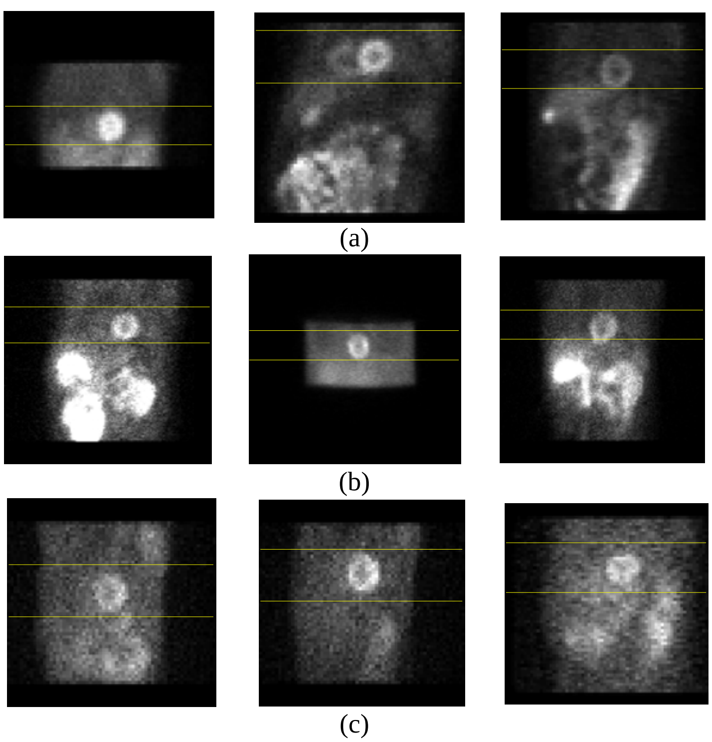


Fig. 2. Flowchart for automatic localization of LV myocardium from SPECT thoracic planar image

III. Experimental Results and Discussion

This section analyzes the performance of our proposed automated method; experiments were done on 54 images with 25 rest studies and 29 stress studies using Thallium 201 (Tl-201) and Technetium 99m (Tc-99m)-labeled agents. Tc-99m labeled agents have the higher resolution collimator than the Tl-201 [7] [8]. Our proposed method works for both Tl-201 and Tc-99m sestamibi planar images. The study was conducted for 14 male and 6 female patients with the age of 05 - 81 years old. 44 test cases were static cardiac SPECT imaging and 10 were dynamic SPECT cardiac imaging. Dynamic cardiac SPECT images provide improved information contrast compared to static images for myocardial perfusion SPECT studies [8]. Our proposed method is working correctly for Step and Shoot imaging acquisition mode and continuous mode of image acquisition. In continuous mode of image acquisition the camera moves continuously and acquires each projection over an angular increment [1]. This result will produce small amount of blurring due to camera motion. The cardiac planar images were acquired using LEAP and LEHR collimators. Generally, LEAP collimators are used for Tl-201 studies and LEHR collimators are suggested for dual isotope studies. Twenty-four studies were acquired on a single detector head camera, 20 studies on a double detector head camera and 10 studies (dynamic SPECT imaging) on triple headed detector camera [10]. 33 test cases on Tc99m SPECT acquisition with a LEAP collimator high-resolution study and 21 were Tl-201 SPECT acquisition with low-resolution study [10].

Fig.3. shows the output of automatic heart localization with the proposed approach. Fig.3 (a), (b), (c), (d) and (e) shows the localization of the heart for different type of images (Tomo, Gated-Tomo, Dynamic-Tomo) with different labeled agents (Tc99m and Tl-201). All the images shown are Best Left Anterior Oblique (BLAO) slices calculated using eqn.1. It can be seen from the Fig.3. that in all the different cases the heart localization algorithm perfectly located LV myocardium.



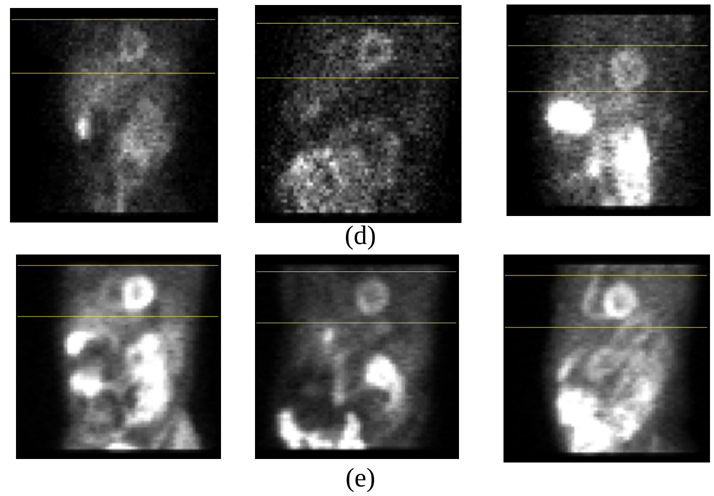


Fig.3 Automatic Heart Localization and reconstruction limits are marked by yellow lines for different types of images, (a) Tomo, step & shoot static rest test images with 64 x 64 image size using Tc-99m labeled agent, (b) Tomo, continuous dynamic rest test images with 128 x 128 image size using Tc-99m labeled agent, (c) Tomo, step & shoot static rest test images with 64 x 64 image size using Tl-201 Labeled agent, (d) Gated-Tomo, step & shoot static rest test images with 64 x 64 x 512 image size using Tc-99m labeled agent and (e) Tomo, step & shoot static stress test images with 64 x 64 size using Tc-99m labeled agent.

IV. CONCLUSION

The proposed method for Automatic localization of LV myocardium from thoracic SPECT planar image is a fully automated process. Experimental result shows that the algorithm produced correct results for all the test images (totally 54 test images were used)

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