otion orrection of SPECT rojection before econstruction

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ABSTRACT

In Single Photon Emission Computed Tomography (SPECT), the data acquisition occurs over a relatively long time, typically in the range of 5-30 minutes. During this period, the patient must lie still to guarantee the image quality. Nevertheless, patient movement has frequently been reported in clinical applications. This movement causes misalignment of the projection frames, which degrades the reconstructed image and may introduce artifacts. However, the ability to detect and correct for the motion using a computational method is valuable for quality assurance of SPECT imaging.

In this work a correlation function based on Linogram and Sinogram of the projection is evaluated in order to estimate the occurred motion and correct it for the best alignment.

By our implemented method the motion artifacts of our cases reduced considerably and our results showed that the misalignment (motion) between the projections could be found with a small error depending on the resolution of the images (pixel size), and the time and duration of the applied motion during the course of projection acquisition.

Keywords

SPECT, patient motion, motion correction, correlation function, motion artifacts

1. INTRODUCTION

In single photon emission computed tomography (SPECT), the data acquisition occurs over a relatively long time, typically in the range of 5-30 minutes. During this period, the patient must lie still to guarantee the image quality. Nevertheless, patient movement has frequently been reported in clinical applications. This movement causes misalignment of the projection frames, which can cause quantitative and qualitative image artifacts in reconstructed images [1-3]. Different methods have been proposed for detection and correction of motion in SPECT studies. Eisner et al. [4] presented a motion correction method based on cross-correlation of summed horizontal and vertical profile of successive projections. Chen et al. [2] used phase only matched filtering to compare adjacent views for detection of lateral and axial motion in SPECT studies. Lateral motion could only be detected by compression of opposing views. This is not always possible because of attenuation in cardiac studies. Geckle et al.[5] described an algorithm called 'diverging square' for tracking the center of the heart in successive projections and correcting its motion based on realignment of the center to a fixed point in space. Cooper et al. [6] detailed an algorithm called 'two dimensional fit' in which an operator defined circular region of interest, tracks the heart in successive frames. Germano et al.[7] proposed 'temporal image fractionation' method while uses a three-interval dynamic study acquisition with the best 2 or 3 dynamic files summed into a single static file for reconstruction.

Comparison of this motion correction methods showed that methods must accurately detect axial motion and cross-correlation was most accurate in detecting lateral motion [8].

Also there are other methods which most of them use cross-correlation function for motion detection.

Passalaqua [9] uses the dual scan method, which consist of acquiring a fast scan, followed by a regular slow scan. The motion is then corrected using the summed one dimensional correlation method. Barakat et al. [10] proposed an algorithm to detect motion in projection data from triple scan SPECT imaging. This algorithm permits the acquisition of three full sets of SPECT data which can be adequately combined in order to reconstitute a motion-free set of projection data. These methods similar to 'temporal image fractionation' method are not routine used methods in SPECT imaging and also eliminate projections in which obvious motion occurred; therefore some of system data acquisition will be eliminated.

In this study, a correlation function based on Linogram and Sinogram of the projection is evaluated in order to estimate the occurred motion and to correct it for the best alignment.

2. MATERIALS AND METHODS:

The technique of acquiring SPECT images was similar to the routine daily clinical studies. The images were acquired on a ADAC SPECT system with step and shoot mode, circular orbit, 32 stops (20 seconds and 30 seconds), 64x64x16 and 64x64x8 matrix, a low energy-high resolution (LEHR) collimator (for Tc-99m) and high energy-general purpose (HEGP) collimator (for I-131) and scanning over 180°. To evaluate the process some axial displacements (±1-3 pixels) was applied initially on several frames of a point source object. Moreover, an object comprising of few point sources in space, a line source, and some patient data was tested by the proposed method.

In this work, a program was written for showing the SPECT system images in cine mode for evaluation of motion qualitatively. Then, Linogram(vertical profiles) and Sinogram(horizontal profiles) of the projection was obtained for qualitative evaluation of patient motion. Using this method, enable visualization of some sudden movements on viewing screen.

For quantifying the motion and finding the time of occurrence, one-dimensional correlation function was applied between profiles of continues frames, magnitude and time of motion obtained from the following equation:

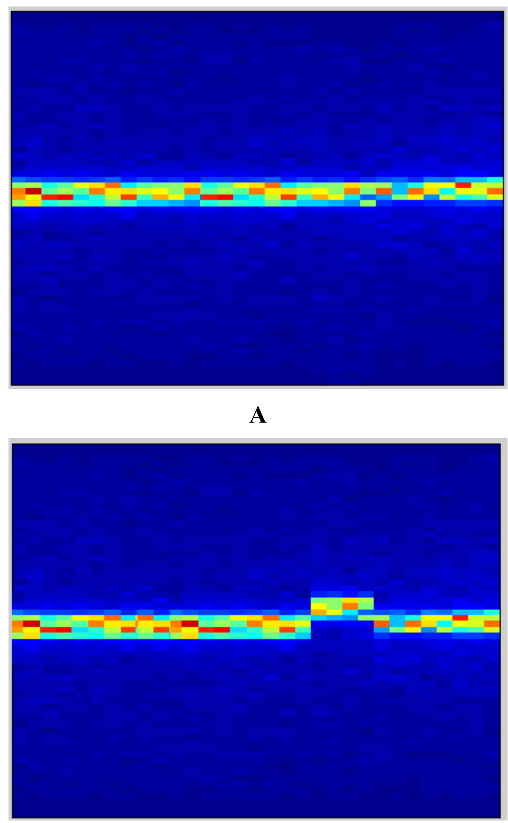
$$CC(d) = \sum_{i=1}^{M} x(i) \times y(i+d)$$

In this equation M is profile points and d is distance parameter. x and y are summed profiles of two successive frames.

The pixel size of image was 6mm×6mm. By converting the image from 64×64 to 128×128 before motion correction with the same algorithm the detection accuracy was increased to 0.5 pixels(≈3 mm). Also, to increase motion detection accuracy, we fitted a parabolic on the maximum point and the adjacent points of correlation series and rounded its maximum to integer number.

3. RESULT AND DISCUSSION:

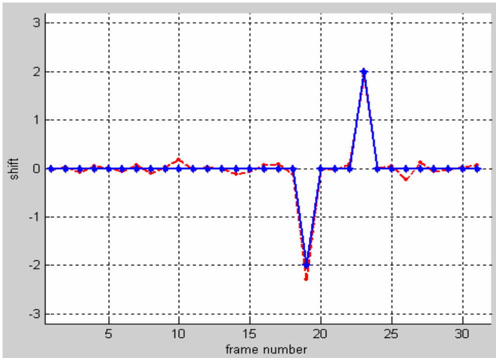
The result from a point source that moved 2 pixels (1.2 cm) during 4 frames and its related Linogram is shown in fig. 1. The result of performing the motion correction program are illustrated in fig. 2.



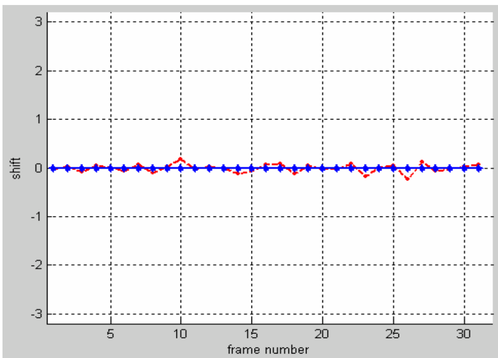
A

B

Figure 1: the Linogram of a point source with moving it 2 pixels (1.2 cm) starting from the first 2 seconds of frame 20 until the latest 2 seconds of frame 23. A: before motion correction, B: after motion correction.



A



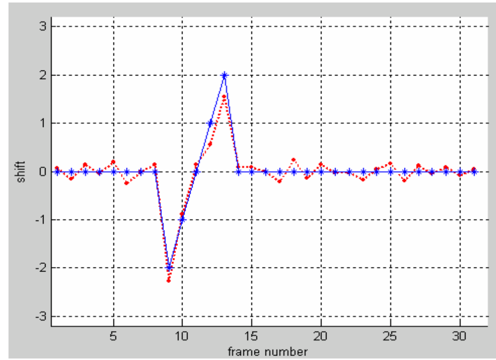
B

Figure 2 : the result of performing the motion correction program for the point source that moved 1.2 cm (≈2 pixels) in the first 2 seconds of frame 20 in the rotation axis direction until the latest 2 seconds of frame 23. A: before motion correction, B: after motion correction.

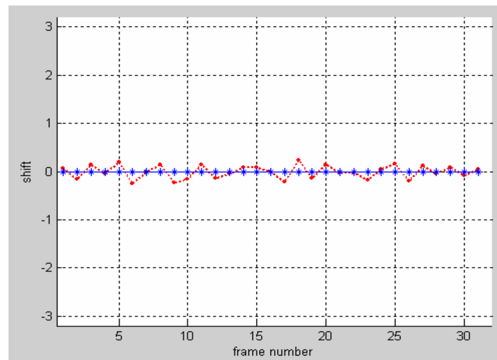
In an alternative test, the projection of point source was obtained in 32 frames, each with duration of 30 seconds. The source was moved 2 cm (≈3 pixels) in frame 10 and corrected manually in frame 13. The output result of running the detection program is illustrated in fig. 3.

The best amount of movement detected between frame 9 and 10 was 2 pixels because they were partially moved in the beginning. This misalignment was also happened between frames 10 and 11 where there was a partial movement during the course of projection (eg; only a movement of one pixel was detected). This situation was also the same for frames 13 and 14 and for frames 12 and 13.

Our tests showed that the time of motion starting in the specific frame and its time duration is very important. Our algorithm works on the basis of correlation between any moved frame (projection) and all the frames in which is stable.



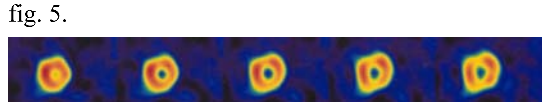
A



B

Figure 3: the result of running motion detection program for the point source that was moved 2 cm (≈3 pixels) in frame 10 and was corrected manually in frame 13. A: before motion correction, B: after motion correction.

We applied the algorithm on patient data as well. After the routine imaging we asked the patient to take another exam with some known movement implied to patient. Some of slices in short axis, before and after motion correction, are seen in figure 4. As you can see in the fig. 4 the motion artifact is reduced considerably after motion correction. The result of running motion detection program before and after motion correction for this patient is seen in fig. 5.



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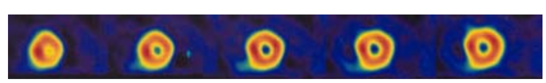
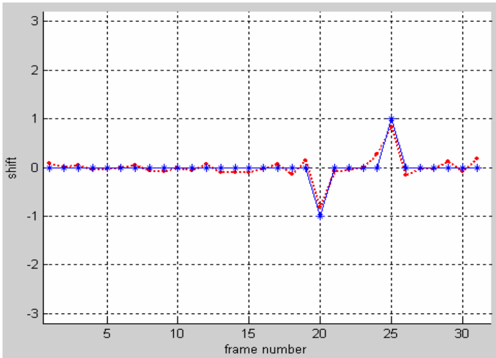
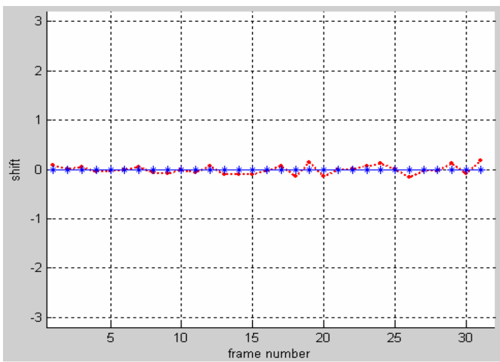


B

Figure 4: some of slices in short axis. A: before motion correction, B: after motion correction. Motion artifact is reduced considerably after motion correction.



A



B

Figure 5: the result of running motion detection program for the patient's image. In frame 21, patient moved 6 mm (≈1 pixel) and moved back in the frame 25. A: before motion correction, B: after motion correction.

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