FINDING CLOSE PROXIMITY OF HEART IN PET IMAGES AS PREPROCESSING FOR CONTOURING AND SEGMENTATION OF LEFT HEART VENTRICLE MUSCLE

R. Bilko*, T. Pałko*

* Institute of Precision and Biomedical Engineering, Warsaw University of Technology,
Św. A. Boboli 8, 02-525 Warszawa, Poland

Rafal.Bilko@rfb.pl, palkot@mchtr.pw.edu.pl

Abstract: Positron Emission Tomography may be used for functional imaging of left heart ventricle muscle. Automatic heart area assessment in whole data volume may be used as a method of quantitative evaluation of PET data. This paper aims at presenting an automated method of finding close proximity of heart area in PET data.

Introduction

Positron emission tomography (PET)[1] is a method used for imaging organ function. In case of cardiac studies it allows determination of ischemic parts of heart muscle. Such an information is necessary for diagnosing and treatment planning. Some methods of quantitative evaluation of PET data require determination of the area of left heart ventricle. This paper aims at presenting an automated method of finding close proximity of heart that may precede contouring or segmentation of the left heart ventricle in PET images using tagged NH_3 or rubidium as a radioactive marker. Assessment of close proximity of heart increases the probability of correct contouring or segmentation. It also reduces the amount of necessary calculations.

Materials and Methods

Data used for algorithm development was obtained from PET Center of University Hospital in Zürich. Data used for the development of the algorithm comprises a database with results of rest and stress tests performed in 12 patients with tagged NH_3 used as radioactive marker and 2 patients examined using rubidium, which where registered at different research centers. Before image processing the data has to be reformatted, so the hearts long axis becomes parallel to the Z axis of data set. Image data has been read and written using Pmod software developed by PMOD Technologies Ltd.

Sample cross-section of the image of the cardiac muscle perpendicular to the long axis of the heart is shown on figure 1. This image contains large hepatic area (area no. 1) and cardiac muscle (area no. 2).

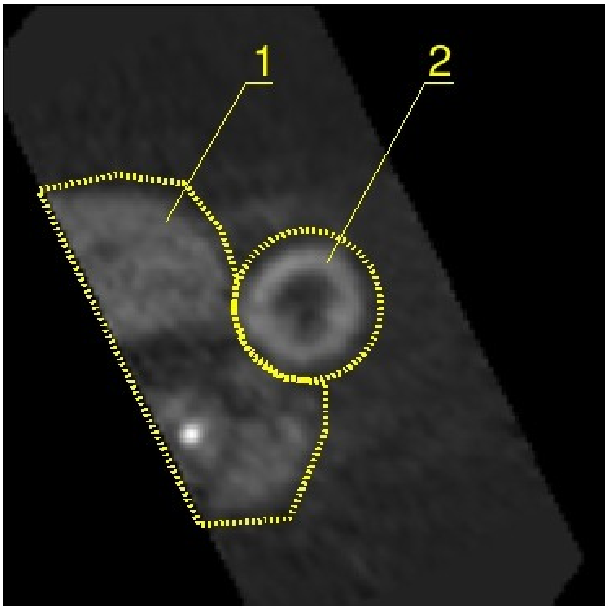

Figure 1: Cross-section of the cardiac muscle, perpendicular to the long axis of the heart. 1) Hepatic area, 2) area of the left ventricle of the cardiac muscle.

Finding close proximity of the cardiac muscle consists of two stages. In the first stage the data is equalized with a 18mm wide Gaussian filter. This process aims at equalizing non-homogeneities that may appear in the liver and heart image. As a rule, the cardiac muscle has more uniform character than the liver and activity measured from the PET image should be constant within some limits. Due to that homogeneity use of smoothing filter should not result in any changes in characteristics of the heart wall image. Hepatic area of PET image contains large number of local minimums, which are caused by anatomical properties of liver which results in its activity seen in PET image. Smoothing filtering eliminates those local minimums resulting in uniform liver image. This

ISSN: 1727-1983 © 2005 IFMBE

filtration is followed by 3x3 edge filtration, with coefficients matrix as shown in figure 2.

-1	-1	-1
-1	2	-1
-1	-1	-1

Figure 2: Edge filter coefficients matrix.

In the second stage, the image is a subject to a process called Watershed Segmentation [2][3][4]. This process is similar to natural phenomenon of land flooding. Brighter (more intensive) pixels considered as points of higher altitude are flooded later. Depending on used convention, less intensive pixels can be considered as placed higher, so that brighter areas are flooded before darker are. In both cases areas considered as "lower" are flooded. Rising water level results in expansion of flooded area into its proximity, covering higher areas. In analytical implementation this is done by checking all the points placed next to every "flooded" pixel, included in water-area. If any of near-by pixels fulfills conditions of being flooded, then it becomes marked as "flooded". In this work, the condition of flooding was as follows:

$$i \leq n * p + min \qquad (1)$$

where:
i – intensity of examined pixel,
n – number of discrete water level rise,
p – value of discrete water level rise,
min – minimal value of image intensity.
Value of discrete water level rise was calculated as fallows:

$$p = (max - min) / k \qquad (2)$$

where:
max – maximal value of image intensity,
k – number of water level rise.

When water of two different areas is about to meet a dam is placed between them. This dam is called watershed line.

Smoothed and filtered data is subject to following iterative processing:

1. Image is segmented using watershed segmentation. Number of levels of segmentation varies from 2 up to 12. Intensity value of original image pixels is assigned to every point of watershed line.
2. Based on image of watershed lines for whole data set, a maximum intensity projection (MIP) image along Z axis is calculated.
3. Obtained image is smoothed, filtered using edge filter and processed using watershed segmentation. Watershed lines are present only in the area of cardiac muscle. Dimensions of obtained watershed lines are examined in X and Y direction. If shorter dimension is equal or larger than 90mm it is assumed, that close proximity of heart has been correctly assessed. Value of 90mm corresponds with anatomical heart dimensions [5]. If this condition is not fulfilled, second stage of analysis is repeated. Two numbers of water level rise are examined – 3 and 4.

Figure 3 shows watershed line image assessed in the last step of iterative processing, with pixel intensity obtained from original image. Figure 4 shows MIP image of watershed lines from figure 3. Figure 5 shows watershed lines calculated from the data shown in figure 4.

Figure 3: Watershed lines (negative) formed on image shown in figure 1, with intensity obtained from original image (fig. 1).

On the basis of calculated XY matrix, 3D matrix is determined with Z dimension equal to the number of original data planes. Further analysis is carried out only for data located within a rectangle circumscribed on the largest watershed line found.

Figure 4: MIP image (negative) along Z axis, created from watershed lines.

Figure 5: Image of watershed lines obtained from MIP image shown on figure 4.

Results

Sample image of close proximity of heart on the basis of data from figure 1 is shown in figure 6.

Table 1 below presents results produced by the algorithm described above for sets of data obtained from 5 different patients examined with usage of tagged NH_3 and 2 with rubidium. First column presents used radioactive marker. Second column shows original image dimensions i X and Y direction in mm. Third column presents heart close proximity area dimensions.

Radioactive marker	**Original dimensions (X x Y [mm])**	**Proximity dimensions (X x Y [mm])**
NH_3	320 x 320	117 x 117
NH_3	320 x 320	112,5 x 105
NH_3	320 x 320	107,5 x 110
NH_3	320 x 320	110 x 110
NH_3	320 x 320	115 x 122,5
Rubidium	525 x 525	150 x 150
Rubidium	525 x 525	137,5 x 137,5

Table 1: Example of results obtained for examined data.

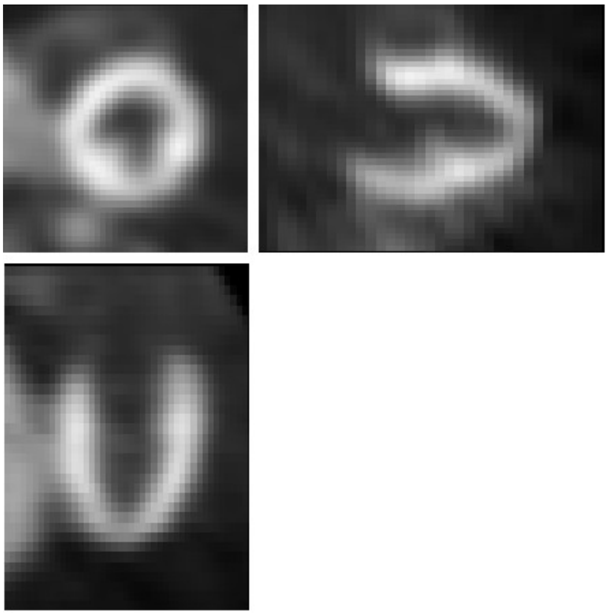

Figure 6: Image of assessed close proximity of heart.

Discussion

PET imaging becomes a popular diagnostic method in cardiology. Reconstructed image usually does not include all useful data. For this reason analysis of whole image is not very efficient. Especially segmentation and contouring of heart muscle within whole image may require a lot of calculation time. Results presented in this work prove that application of developed algorithm may reduce analyzed area of the image.

Presented method assumes parallelism of heart long axis to the image Z axis. Research show that anatomically hearts long axis can be deviated up to 25° from image Z axis. Such case is shown in figure 7. Results obtained for this particular data are shown in figure 8. Figure 9 presents the same examination results with the long heart axis parallel to the image Z axis. Figure 10 shows results of algorithm application for this data. During examination algorithm proved to be resistant to any mistakes made by operating staff.

Described algorithm was tested also using SPECT data and have proved useful also for this kind of data.

ISSN: 1727-1983 © 2005 IFMBE

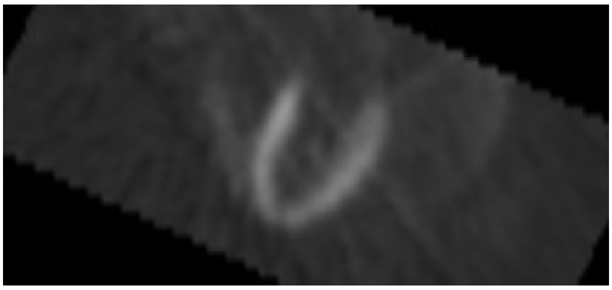

Figure 7: Image of cardiac muscle with long axis deviated by 25° from image Z axis – viewed in XZ plane.

Figure 8: Close proximity assessed for hart image presented in figure 7 – viewed in XZ plane.

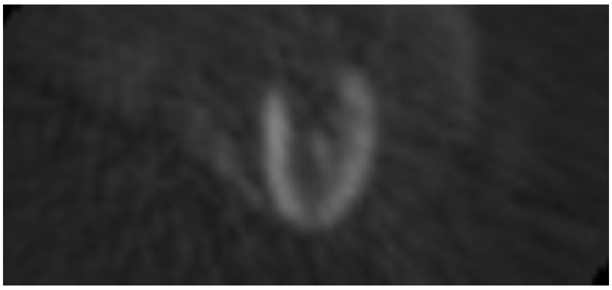

Figure 9: Image of cardiac muscle with long axis parallel to image Z axis – viewed in XZ plane.

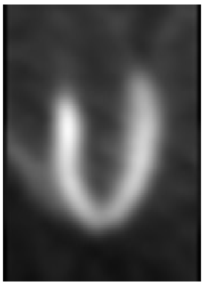

Figure 10: Close proximity assessed for hart image presented in figure 9 – viewed in XZ plane.

Conclusions

Presented method of finding close proximity of heart gives positive results for all evaluated images. It is fast and effective. It may also be used for SPECT images.

References

[1] GRZEGORZ PAWLICKI, TADEUSZ PAŁKO, NATALIA GOLNIK, BARBARA GWIAZDOWSKA, LESZEK KRÓLICKI (2002): Fizyka Medyczna, Volume 9 of Biocybernetyka i Inżynieria Biomedyczna, Akademicka Oficyna Wydawnicza Exit, Warszawa, pp. 309-313
[2] LESZEK CHMIELEWSKI, JULIUSZ KULIKOWSKI, ANTONI NOWAKOWSKI (2003): Obrazowanie Biomedyczne, Volume 8 of Biocybernetyka i Inżynieria Biomedyczna, Akademicka Oficyna Wydawnicza Exit, Warszawa, pp. 105-112
[3] THEO PAVLIDIS (1987): Grafika i przetwarzanie obrazów, Wydawnictwa Naukowo-Techniczne, Warszawa
[4] MILAN SONKA, VACLAV HLAVAC, ROGER BOYLE (1999): Image processing, analysis, and machine vision, Brooks/Cole Publishing Company, pp. 186-189
[5] SCHNITTGER I, GORDON EP, FITZGERALD PJ, POPP RI (1983): Standarized intracardiac measurements of two-dimensional echocardiograpaphy, J Am Coll Cardiol; pp. 2:934-8