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Application of ASFCM Segmentation

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Abstract-MRI and CT images are commonly used for disease detection. Another method used in this area – Positron Emission Tomography (PET) for image analysis. For clinical PET scanning, positron emission radioactive isotopes are injected into the human body. The following are the major drawbacks of this type of scanning: (1) radio active isotopes have side effects on patients and (2) PET scan is expensive. For these two reasons, PET simulators are needed for physical and clinical research. This work proposes a new method to simulate the PET image of the brain with Monte Carlo simulation in Matlab. For the simulation, MRI and CT based, segmented image, is used as the original image. In order to produce a correct segmentation of MR Images the intensity non - uniformity (INU) artifact needs to be modelled and compensated. Adaptive Spatial Fuzzy Center Means segmentation is used for brain tissue segmentation of MRI. It is based on Fuzzy Center Means that address both INU artifact and local spatial continuity.

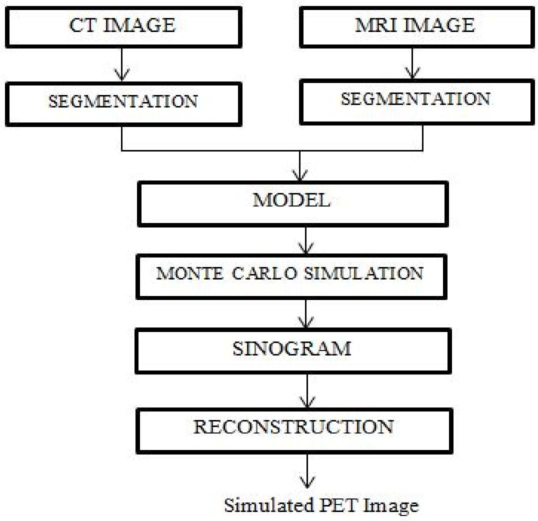
Key word-INU artifact, FCM, ASFCM, membership values, clusters, fuzziness factor

I. INTRODUCTION

For PET scanning positron emission radioactive isotopes are injected to the human body. The following are the major drawbacks of this type of scanning: (1) radio active isotopes have side effects on patients and (2) PET scan is expensive. For these two reasons, PET simulators are needed for physical and clinical research.For the simulation of PET most commonly used method is GATE (Geant 4 Application for Tomographic Emission).It uses complex algorithms. In this simulate the PET tumor images using Monte Carlo simulation that will be implemented in Matlab.

For the simulation, MRI and CT based, segmented image, is used as the original image. Image segmentation plays a vital role in image analysis which is considered as the obstruction in the development of image processing technology. MRI is characterised by composition of small differences in signal intensities between different tissue type. Thus uncertainties and ambiguities are introduced in image formation. The most important obstacles are noise, partial volume effect (PVE) and intensity non-uniformity (INU). PVE means multiple tissue types contribute to a single pixel. INU is pixel belonging to same tissue to be observed with different intensity. In order to produce correct segmentation of MRI, INU artifact needs to be modelled and compensated. Fuzzy Center Means segmentation is resistant to some degree of intensity non-uniformity artifact in MRI. Hence use, Adaptive Spatial Fuzzy Center Means segmentation is used. It is based on Fuzzy Center Means that address both INU artifact and local spatial continuity.

II. FLOW CHART



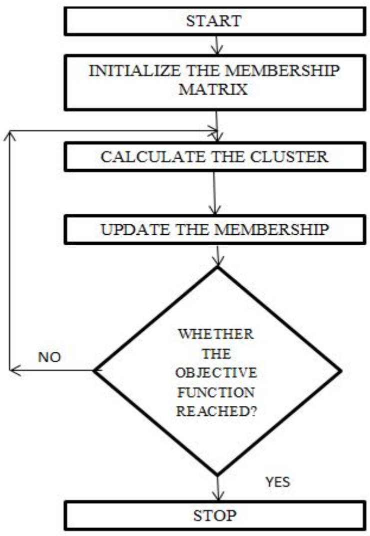
MRI and CT images are used as initial maps. From these attenuation and activity maps are created. MRI images are segmented to 1) extracted brain image, 2) outskin image, and 3) brain tissue segmented image .Brain tissue segmented image means separate grey matter , white matter and cerebrospinal fluid(CSF). Bone is separated from CT image. From the combination of the bone tissue and outskin image attenuation maps [3] were created. Information from all images are required for generate the activity maps [5].Monte Carlo code is used to simulate PET image.

III. SEGMENTATION

Thresholding methods are used for bone tissue extraction from the CT image and Extracted brain image and outskin image from MRI. Fuzzy center means segmentation is not eliminating intensity non-uniformity artifact in MRI. Hence brain tissue segmentation is done by Adaptive Spatial Fuzzy center mean algorithm(FCM)[16]. Adaptive Spatial Fuzzy C-means clustering is a data clustering method. It is based on fuzzy center means that address both local spatial continuity and INU artifact.

3.1 Fuzzy C-Means Clustering

Brain tissue segmentation is done by Fuzzy center mean algorithm(FCM)[16].First, the initial membership matrix is generated and the initial fuzzy cluster centers are calculated. In each step of the iteration, the cluster centers and the membership value are updated and the objective function is minimized to find the best location for the clusters. The process stops when the maximum number of iterations is reached, or when the objective function improvement between two consecutive iterations is less than the minimum amount of improvement specified.



3.2 Adaptive Spatial Fuzzy C-Means Clustering

Spatial relationship of neighboring pixel is important in image segmentation. The neighboring pixels are highly correlated to the feature data. Calculate the distance between pixel and centroid. If the distance is less than threshold value 1e-5 then update the membership matrix. Otherwise segmentaton is performed.

- Membership matrix U randomly select according to the size of the image.
  U=[U_{ij}], 1 ≤ i ≤ c,1 ≤ j ≤ n
  It satisfies the following condition:

$$\sum_{i=1}^{c} U_{ij} = 1 \quad \forall j = 1,2, \dots \dots, n$$

Where U_{ij}- membership grade ,n- number of samples c- number of clusters

- Then calculate the Cluster center
  $$c_i = \frac{\sum_{j=1}^{n} U_{ij}^{m} . x_i}{\sum_{j=1}^{n} U_{ij}^{m}}$$
  Where m ∈ [1,∞] is the weighting exponent xi is the data point
- Calculate distance between the pixel and center

$$d_{ij}^{2} = \left\|x_i - c_j\right\|^2$$

- If the distance is less than the threshold 1e-5 then update the membership matrix
- The new membership matrix is
  $$U_{ij}^{m} = \frac{1}{\sum_{k=1}^{c} (\frac{d_{ij}}{d_{ik}})^{\frac{2}{m-1}}}$$
- Terminating condition: Aims at minimizing the desired function
  $$J_{ASFCM} = \sum_{i=1}^{c} \sum_{j=1}^{n} U_{ij}^{m} \, d_{ij}^{2}$$

IV. MODEL

Attenuation map were generated from combination of bone tissue and outskin image. Information from all images are used to generate activity map. Activity map shows the higher activity level compared to the surrounding brain tissue.

V. MONTE CARLO SIMULATION

Monte Carlo is a numerical calculation method in which random variables plays an important role. It can be applied in medical radiation to a wide range of problems that could not be easily addressed using experimental or analytical approaches.

5.1 Positron Range

Distance between the decay spot and annihilation point is called positron range. From a Gaussian distribution function the range‘d’ will be chosen.

5.2 Annihilation

The positron may travel with specific energy in all 360 degrees. Between 0-360 degree angle is selected.From the uniform distribution -1 to 1 select a number.

Number is greater than 0,the co-ordinate of the annihilation spot is:

$$x_0 = x_a + d * cos\theta$$

$$y_0 = y_a + d * sin\theta$$

Number is below 0,the co-ordinate of the annihilation spot is:

$$x_0 = x_a - d * cos\theta$$

$$y_0 = y_a - d * sin\theta$$

5.3 Photon Transportation

For the photon transportation, by giving a slope of the route. photon angle will be randomly chosen.Annihilation spot decided before, the photon transportation be presented as:

$$y = k (x - x_0) + y_0 \qquad (1)$$

Here the pass way of the photon is (x,y) , the slope of the pass way is k,and the annihilation spot is (x_0,y_0) .

(A, A) is the central point of the PET camera detector ring where 'A' is the radius of the detector ring, then the circle of detectors can be represented as:

$$(x-A)^2+(y-A)^2=A^2 \qquad (2)$$

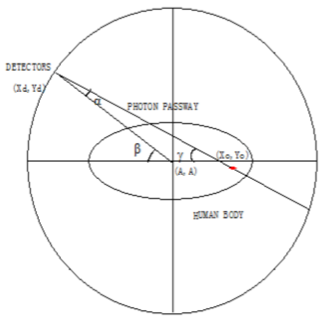
The (x_d, y_d) co-ordinates of the detector which the photons entered be calculated from the equation (1) and (2):

$$x_d=\frac{-2(y_0-kx_0-2A)\pm\sqrt{4(y_0-kx_0-2A)^2-4(y_0-kx_0-2A)^2(1+k^2)}}{2(1+k^2)}$$

$$y_d= k(x_d-x_0)+y_0$$

VI. SINOGRAM

PET scan cantains number of detector ring. Sinogram means how many photons hit the certain detector in the certain angle.The angle between the LOR to the detector line can be calculated from the above three parameter: the coordinates of the central point, the spot where the annihilation happened, and the detector which the photon hit.



Angle can be calculated as:

$$\tan\gamma=\frac{y_d-y_0}{x_d-x_0}$$

$$\tan\beta=\frac{y_d-A}{x_d-A}$$

$$(\tan\alpha)^2=\left(\frac{\tan\gamma-\tan\beta}{1+\tan\gamma\tan\beta}\right)^2$$

Total detector number = $\frac{2\pi * A}{scitilator\ size}$

Scintilator is a small crystal used in the PET scan system. Scintilator size is between 3- 5 mm.

VII.RECONSTRUCTION

The angle α and the detector number which the photon hit reconstruct the image with this information [2].

$$k_p=\tan(\theta+\alpha)(if\ \alpha\ \leq 0^{\circ})$$

$$k_p=\tan(\theta-\alpha)(if\ \alpha\ \geq 0^{\circ})$$

VIII. EXPERIMENTAL RESULTS

IX.

Fig 8.1 Input CT image

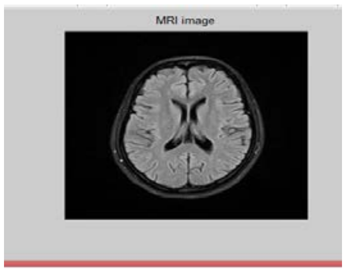


Fig 8.2 Input MRI

Fig 8.3 Bone image from CT

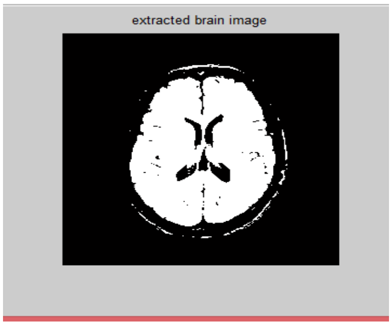


Fig 8.4 Extracted brain image from MRI

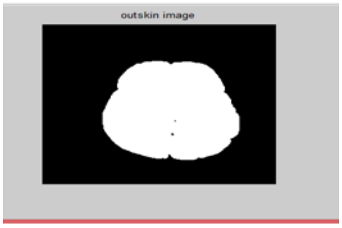
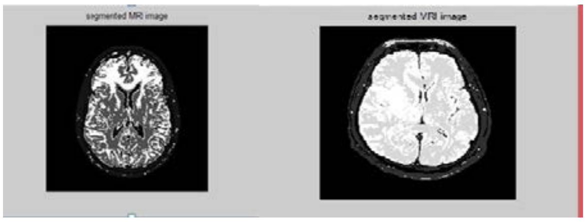
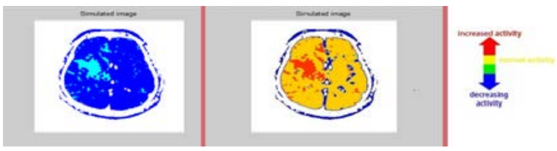


Fig 8.5 Outskin image from MRI



a)Using FCM b)Using ASFCM

Fig 8.6 Segmented MRI



a)Using FCM b)Using ASFCM

Fig 8.7 Simulated PET

CONCLUSION

In this work, the efficiency of the MC Simulation of PET tumor images using CT and MRI is demonstrated by FCM and ASFCM segmentation experiments by applying them to the challenging applications: gray matter and white matter segmentation in MRI.Comparing to clinical PET scan system it is low cost and using the simulated image anyone can understand the diseased portion without the expert advice. The simulation was simpler than the existing methods as it was done in Matlab platform and analytical information is only used. Hence users need not know more details about the internal working details of PET scanning.

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