Hybrid Segmentation Approach to Segment Fetal Cardiac Chambers of Ultrasound images

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***Abstract*— Fetal echocardiography uses ultrasound technique to view heart of the baby even when the baby is in the mother's womb. Obstetricians refer the patients to undergo this procedure if they find any suspicious conditions of having defects in the fetal heart. This test is done usually during 2nd trimester. Fetal ultrasound measurements are one of the most important factors for high quality obstetrics health care in order to estimate the Gestational age, exact delivery date and growth of the fetus.The standard 2D ultrasound imaging technique examines the fetal heart in different views. The information related to the cardiac size, structure, rhythm and movement can be obtained in four chamber view. Various congenital defects can be visualized by the examination of fetal cardiac chambers. It is very difficult to locate the cardiac chambers and do the relevant measurement, hence it is challenging work to researchers of biomedical community.**

A semi automated method of segmentation has been proposed in this experimental study to segment the fetal heart chambers using Possibilistic c-means clustering technique. The Ultrasonic images of fetal heart having four – chambers in apical view was used in order to do the study with simulation. The input fetal cardiac frame was denoised and enhanced. The enhancement of the input image was carried out by converting it in to gray image. This was then converted to binarized image. On the selected chambers the region growing technique followed by PCM was used to segment the cardiac chambers. Finally the region properties were used to measure the ventricles that is the left ventricle and right ventricle of the fetal heart and LV/RV estimation is done based on standard values.

The ratio of the width of left ventricle and right ventricle were calculated which closely matched with the theoretical width considered as the standard for different gestation week. The proposed semi – automated technique need to be validated before being used for assessment as the clinical tool by large datasets.

Index Terms—; fetal cardiac chamber, Possibilistic c means clustering, region growing, left ventricle, right ventricle, LV, RV, LV/RV, segmentation.

I. INTRODUCTION

The growth of the fetus in the mother's womb can be assessed using Ultrasound imaging technique. This clinical procedure gives the status of the fetus both anatomically and functionally. The important information related to the pumping action and abnormalities can be derived from the observation of fetal cardiac chambers. A literature review focuses on the importance and requirements of fetal cardiac chamber measurement by fetal anatomy of ultrasonic images [5].

In spite of having several qualitative procedures and techniques for recognizing fetal cardiac chambers , there is still a necessity to derive qualitative procedure for detection and recognition of the fetal cardiac defects. Several Researchers have attempted to detect whether the cardiac chambers are present or not in order to do the relevant measurement and to assist in diagnosing the fetal cardiac anomalies. Four chamber view is used for clinical assessment of heart chambers by the sinologist [2] – [5]. Research work has been initialized in the field of biomedical to detect the fetal cardiac chambers. There is tremendous development of qualitative procedures in this regard from past to present [4] – [8]. Yinhui Deng etal have proposed a procedure to detect the fetal heart using anisotropic diffusion and Rayleigh-trimmed filter in 3-dimensional space. An active cardiac model has been developed by them to detect fetal cardiac chambers. Sriraam etal, have made an attempt to detect fetal cardiac chambers by using histogram based segmentation technique [7]. Sridevi et al have proposed a system of Probabilistic Patch Based Maximum Likelihood Estimation (PPBMLE) to highlight the anatomical fetal cardiac structures. The segmentation is done on the resultant image using fuzzy Connectedness image segmentation process. Seven different feature extraction models were used to extract 32 diagnostic features. The classification is done by the combination of Fisher Discriminant Ratio (FDR) analysis and Adaptive Neuro Fuzzy Inference System (ANFIS). Prenatal TACHD was perceived and clinical results were shown. The proposed system has proven to give better results comparative to other classifiers [9]. The proposed method uses hybrid segmentation method involving region growing and PCM based threshold technique to segment the fetal cardiac chambers. Finally LV/RV ratio are estimated to identify the condition of chambers of fetal heart by comparing with the standards been globally used by the technicians [10].

II. METHODOLOGY

A. Data

Ultrasonic still frames extracted from cine – loop sequences pertaining to different gestational age were considered to segment fetal cardiac chambers [5], [7]. All the ultrasonic cine

loop sequences were validated and assessed clinically by the clinician before being used for the research study. Quantitative analysis was performed on a total of 93 sill images

B. Proposed Scheme

Fig. 1 depicts the flow diagram of the proposed technique of hybrid segmentation to detect and measure the chambers of fetal heart considered for this proposed work.

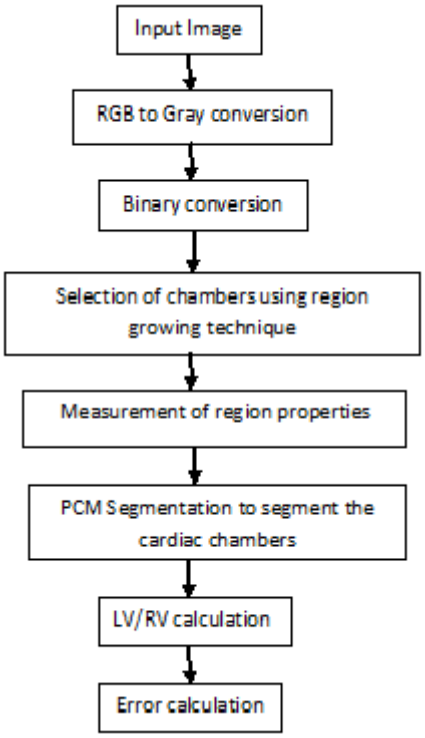


Fig. 1. Fetal chamber detection and measurement flow diagram

The ultrasound still frame in 2-D is taken as the input. The speckle noise present in the input image is removed by performing RGB to Gray conversion followed by binary conversion of the resultant image. The region of interest (fetal heart) is detected using region growing technique. The region properties are measured. The fetal cardiac chambers, i.e., LV and RV are detected using the Possibilistiic c means clustering segmentation. Results are evaluated by converting pixels into centimeters of detected chambers. The ratio of LV/RV is calculated and compared with the golden standard to find the error tolerance.

C. Region growing technique

The automated region growing technique is been used in this paper. The method succeeds with the seed pixel and the threshold selection effectively. With the prior knowledge, the user has to manually control the process of region growing technique by proper selection of seed pixel and threshold. Texture features are used to automatically calculate the seed point and threshold in this proposed work. In this section we review techniques that are adapted to support our system A. Automatic selection of seed point 1) Co-occurrence probability features: the common method to extract the texture feature is been proposed by Haralick et al [13] using co-occurrence matrix. The co-occurrence probabilities are determined by the interpixel distance(d) and direction (s) with the window size and the gray level quantizer. The co-occurrence matrix consists of all pair wise combination of gray level denoted as (i, j) in the spatial window which is of fixed size in all probabilities. The matrix stores the co-occurring probabilities of some structural aspects indexed as i and j. Some local image textures like roughness and smoothness i.e., the qualitative characters also gets reflected in this matrix values. Energy, entropy, contrast and correlation are the four that are calculated at direction ş=0 and inter pixel distance d=1.

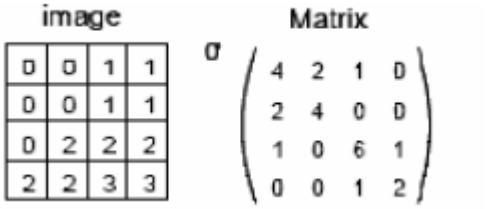


Figure 2. A 4X4 image with four gray levels and co occurrence matrix

The non-homogeneous region with homogeneous region is easily differentiated by the use of energy and entropy as co-occurrence features. The value of these features is and low for non homogeneous regions and high for homogeneous regions. In the ultrasound images the fetal cardiac regions appear to be homogeneous, hence these features are capable of identifying a seed pixel from the fetal heart region.

D. Possibilistic C Means (PCM)

PCM is a type of unsupervised clustering technique. The PCM generates the component belonging to dense region in the data set. In the PCM strategy each cluster is independent of the other clusters. The objective function of the PCM, JPCM is denoted in the equation (1),

$$J_{PCM}(V,U,X) = \sum_{i=1}^{c}\sum_{j=1}^{n}\mu_{ik}^{m} d^2(X_j, v_i) + \sum_{i=1}^{c}\eta_i \sum_{j=1}^{n}(1-u_{ij})^m$$

eqn 1

where, ηi represents the mobilization scale parameter at the ith cluster and it's membership value becomes 0.5, Uij denotes the value of possibilistic typicality of training sample Xj pertaining to the cluster i as represented in Equations (2) and (3),

m is the weighting factor of the possibilistic parameter ranging [1, ∞] with c representing the number of clusters where 1≤k≤n and n is a real number between 1 to ∞.

$$\eta_i = \frac{\sum_{j=1}^{n}\mu_{ij}^{m}||x_j - v_i||^2}{\sum_{j=1}^{n}\mu_{ij}^{m}}$$

eqn 2

$$u_{ij} = \frac{1}{1+\left[\frac{d^2(x_j,v_i)}{\eta_i}\right]^{\frac{1}{m-1}}}$$

eqn 3

PCM is been initialized by other cluster approaches. In PCM technique the clusters are immobile and each cluster results due to one data point. Both characteristics of Fuzzy and Possibilistic C means clustering approach termed as FPCM is been incorporated in this experimental study. In order to converge globally to minimum value a suitable initialization is important for all the algorithms. The important factors for selecting a correct feature of data substructure in clustering technique are memberships and typicalities. In FPCM the objective function depends on these factors as illustrated in Equation (4) with the constraints as denoted in Equations (5) and (6),

$$J_{FPCM}(U,T,V) = \sum_{i=1}^{c}\sum_{j=1}^{n}(\mu_{ij}^{m} + t_{ij}{}^{n})\, d^2(X_j, v_i)$$

eqn 4

$$\sum_{i=1}^{c} \mu_{ij} = 1, \forall j \in \{1, \ldots, n\}$$

eqn 5

$$\sum_{j=1}^{n} t_{ij} = 1, \forall i \in \{1, \ldots, c\}$$

eqn 6

Iterative process yields the result to the objective function.

With the help of equations 5 and 6 with the below equations the degrees of membership, typicality and the cluster centers are updated.

$$\mu_{ij} = \left[\sum_{k=1}^{c}\left(\frac{d^2(X_j,v_i)}{d^2(X_j,v_k)}\right)^{2/(m-1)}\right]^{-1}, 1 \le i \le c, 1 \le j \le n.$$

$$t_{ij} = \left[\sum_{k=1}^{n}\left(\frac{d^2(X_j,v_i)}{d^2(X_j,v_k)}\right)^{2/(n-1)}\right]^{-1}, 1 \le i \le c, 1 \le j \le n.$$

$$v_i = \frac{\sum_{k=1}^{n}(\mu_{ik}^{m}+t_{ik}^{n})X_K}{\sum_{k=1}^{n}(\mu_{ik}^{m}+t_{ik}^{n})}, 1 \le i \le c.$$

Cluster centers for each cluster in Possibilistic Fuzzy C Means (PFCM) are constructed by memberships and possibilities. Relative typicality describes the Membership; the labeling of the data point depends on the degree at which the data fits into the cluster with respect to other clusters. Absolute typicality defines the Possibility which reduces the noise effects and determines the degree of belonging of data point to a cluster PFCM is the hybridization of PCM and FCM which in turn avoids the problems associated with PCM and FCM. The defect of noise sensitivity present in FCM is minimized by PFCM. This also reduces the problem of clusters coincidence present in PCM in turn excludes the estimation of centroids.

E. Cardiac chamber measurement

The fetal cardiac chambers are measured automatically which declares the fetal heart condition. This procedure helps in identifying the defects of fetal heart like septal defects and congenital issues. Clinical community refers the manual measurements of different gestational proposed by Shapiro etal [10] as golden standards. In this research study the chamber length and width are estimated to find the ratio of Left and Right ventricles

III. RESULTS

For the pilot study, region growing technique and PCM technique was used. Fig. 3 shows the input image with preprocessed images and resultant images after segmentation. A region growing technique is used to extract the fetal heart. Hybrid PCM segmentation technique is used to segment the chambers of fetal heart in a semi-automated way.

Fig 3 (a) input image

Fig 3 (b) RGB – Gray converted image

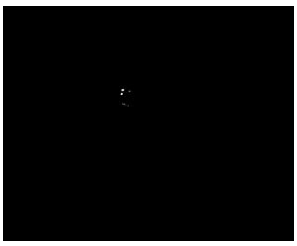
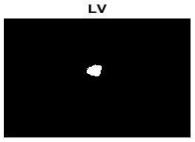


fig 3(c) binary image

fig 3 (d) after region growing technique



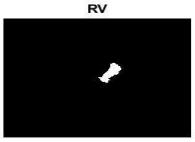


Fig. 3 (e) output image

Fig 3. Input image with preprocessed results and output image

Fig 3, illustrates the results of the preprocessed steps and the resultant output image after segmentation. The given still frame is preprocessed in order to extract the fetal heart. PCM segmentation process is applied to extract the fetal chambers. The LV and RV length of the segmented chambers are measured based on the Euclidean distance incorporating criteria of maximum scale.

Finally results are evaluated by converting the pixels into centimeters of the extracted chambers. Table 1, presents a comparative study of estimated LV/RV with standard measurements and statistical analysis based on P2.5 and P97.5 as reported in [10].

It can be interpreted from the proposed study that the region growing and PCM segmentation is yielding comparable results in terms of the measurement of Left and Right ventricles of fetal heart with theoretical bound.

TABLE.1. COMPARATIVE STUDY

				Left Ventricle			Right Ventricle			LV/RV ratio		
GA	LV	RV	LV/RV	P2.5	SD	P97.5	P2.5	SD	P97.5	P2.5	SD	P97.5
21	0.8	0.8	1	0.58	0.11	1.021	0.58	0.11	1.02	0.74	0.13	1.26
22	0.8	0.6	1.33	0.57	0.12	1.03	0.36	0.12	0.84	1.07	0.13	1.59
20	0.5	0.7	0.71	0.29	0.11	0.71	0.49	0.11	0.91	0.46	0.13	0.97
20	0.6	0.7	0.86	0.39	0.11	0.81	0.49	0.11	0.91	0.60	0.13	1.11
20	0.8	0.7	1.14	0.59	0.11	1.01	0.49	0.11	0.91	0.89	0.13	1.39
21	1	0.8	1.25	0.78	0.11	1.20	0.58	0.11	1.02	0.99	0.13	1.51
20	0.5	0.7	0.71	0.29	0.11	0.70	0.49	0.11	0.91	0.46	0.13	0.97
20	0.8	0.5	1.61	0.5964	0.11	1.03	0.29	0.11	0.71	1.34	0.13	1.86
20	0.8	0.6	1.33	0.59	0.11	1.01	0.39	0.11	0.81	1.08	0.13	1.59
21	0.9	0.6	1.5	0.68	0.11	1.12	0.38	0.11	0.82	1.24	0.13	1.76
20	1	1	1.0	0.79	0.11	1.21	0.79	0.11	1.21	0.74	0.13	1.26
21	0.5	0.5	1.0	0.28	0.11	0.72	0.28	0.1	0.72	0.74	0.13	1.26
20	0.4	0.5	0.8	0.19	0.11	0.61	0.29	0.11	0.71	0.54	0.13	1.06

IV. CONCLUSION

In this work a semi-automated approach is presented to extract the fetal cardiac chambers and do the relevant measurements. In this work the image is enhanced to remove the speckle noise by binarization, pre-processing methods are used to calculate the gradient magnitude and frequency domain approach i.e. region growing technique and finally segmentation of chambers is carried out using Possibilistic C means clustering method. This procedure is carried out on different test cases of various gestational ages to detect the chambers This segmentation approach is carried out using PC running MATLAB which has yielded better results in terms of segmentation and has reduced the time of computation. The results have to be validated with large data sets of different gestational ages of different samples.

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