Wavelet-based Segmentation for Fetal Ultrasound texture Images

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ABSTRACT

This paper introduces an efficient algorithm for segmentation of fetal ultrasound images using the multiresolution analysis technique. The proposed algorithm decomposes the input image into a multiresolution space using the packet two-dimensional wavelet transform. The system builds features vector for each pixel that contains information about the gray level, moments and other texture information. These vectors are used as inputs for the fuzzy c-means clustering method, which results in a segmented image whose regions are distinct from each other according to texture characteristic content. An Adaptive Center Weighted Median filter is used to enhance fetal ultrasound images before wavelet decomposition. Experiments indicate that this method can be applied with promising results. Preliminary experiments indicate good results in image segmentation while further studies are needed to investigate the potential of wavelet analysis and fuzzy c-means clustering methods as a tool for detecting fetus organs in digital ultrasound images.

Keywords: Medical image processing; Wavelet; Fuzzy c-means clustering.

1. INTRODUCTION

Ultrasound is a pulse-echo imaging modality based on interrogation of tissues with high frequency focused sound waves. Its use in medical imaging, particularly of the fetus, has become wide spread because it is inexpensive and safe [1]. Furthermore, because ultrasound images can be produced in real time, the modality allows for imaging dynamic structures such as the beating heart, as well as for exploratory imaging. In case of fetal ultrasound, the examiners evaluate the length of the body and head, the movement of the limbs, and the detection of the different congenital disease kinds.

Generally ultrasound images often have a marked textural appearance. Therefore the segmentation of these images is an essential component of computer-assisted diagnosis system. The purpose of such systems always is to detect the boundaries of different organs from the diagnostic ultrasound images [2]. A method to segment tissues into these categories is an important step that contributes to the diagnosis processes in the field of the volumetric rendering, as well as surface reconstruction, also to compute a high quality 3D visualization of pathological tissue that may be used for irradiation or surgery planning and to control irradiation treatment.

Several texture segmentation algorithms based on extracting features from wavelet transform domain have been proposed recently [3]. In [4] a criterion that utilizes ratio of the mean energy in the four low-frequency channels to that in three middle-frequency channels is suggested to distinguish smooth images from textured images. In [5], [6] a multiple scale approach is introduced and the performance of wavelet packet is investigated. The authors conclude that multiresolution properties of wavelet transforms are useful for applications such as segmentation, classification, and discrimination of textures. Porter [7] proposes an automatic scheme, which can select the optimal features using wavelet analysis. In another work, wavelet packet representations at multiple scales are used as the texture signature, and appropriate features extracted from wavelet decompositions are measured [8]. Based on this information, classification can then be performed. Actually, despite the effort, texture analysis is still considered difficult problem in image processing.

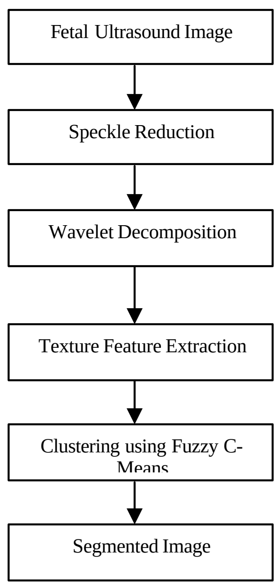


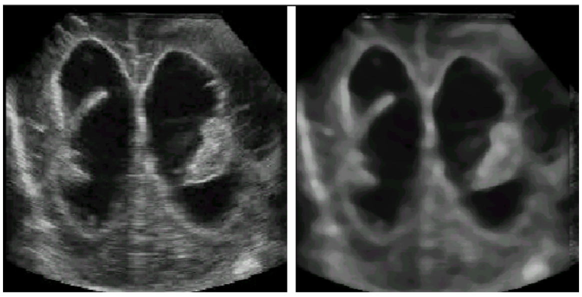
Fig. 1. Block diagram of the proposed segmentation algorithm

In this research, we implement multiresolution wavelet transform for texture segmentation application using The B-spline mother wavelet in the decomposition process [9]. The texture information is extracted using statistic parameters from the multiresolution framework. The fuzzy c-means [10] classifier is employed for the clustering process. This process results a segmented image whose regions are distinct from one another with respect to texture characteristic content. Fig. 1 shows the structure of the proposed segmentation schema of fetal images.

2. ULTRASOUND SPECKLE REDUCTION

Ultrasound Speckle is a phenomenon that occurs when a coherent imaging system is used to image a surface that is rough on the scale of the wavelenght used. Speckle is often modeled as a multiplicative process [11], because fully developed speckle has the property of constant signal to noise ratio. Speckle is a phenomenon common to many coherent imaging systems, such as synthetic aperture radar and laser holograghy. Although it is often viewed as noise, speckle is a signal dependent because it contains information about the subresolvable structure of the tissue. An Adaptive Center Weighted Median filter *(ACWM)* is used to enhance fetal ultrasound images in the first step.

ACWM is non–linear image smoothing and enhancement technique. It is effective at reducing both signal dependent and random noise. Several researchers have experimented with adaptive median and order statistic filters [12], [13],[14]. ACWM filter varies the center's weight from one point to the next by a technique designed to distinguish noise from detail. When the center's pixel in the window is deemed to be more likley to be noise than signal we want to lean towards outputing the median, conversly we want the output biased towards the identity filter when we've got signal. Fig.2(a) shows a hydrocephalus ultrasound image, Fig.2(b) is the image filtered by ACWM.



(a) **(b)**

Fig.2. (a) Original hydrocephalus ultrasound image. (b) Result after filtering by 9x 9 adaptive weighted median filter.

3.WAVELET MULTIRESOLUTION ANALYSIS

The wavelet transform decomposes the fetal ultrasound image into a multiresolution representation, which consists of the low frequency approximation information and the high freqency detailed information. The reader is referred to references such as [15], [16] for details of the two-dimensional orthogonal wavelet transform. Given fetal ultrasound image, the multiresolution representation is generated by successive filtering using quadrature mirror filter [8]. Successive filtering of textured images can be thought as dynamically focusing on the important region of the frequancy domain for the particular texture in the image. Fig 3 shows the subband of the 2-D orthogonal wavelet transform of hydrocephalus ultrasound image.

The b-spline mother wavelet is considered to be the mother wavelet of the decomposion algorithm. It possesses some desirable properties such as being well localized in time and frequency, and being compactly supported. Thus it allows to derive localized contributions of energy to the textured signal in well seperated frequancy channels.

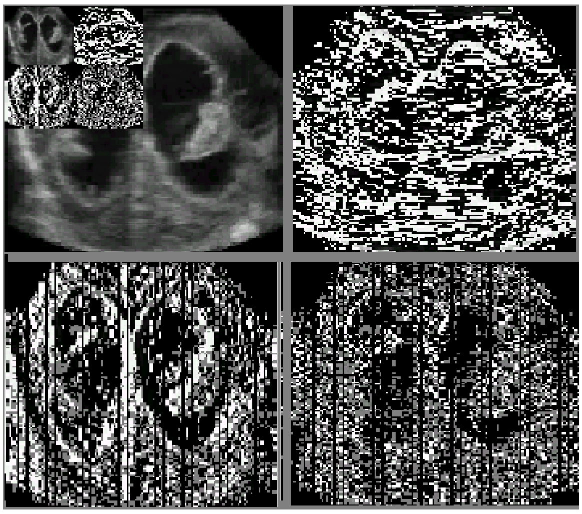


Fig. 3. The subband of the 2-D orthogonal wavelet transform of hydrocephalus ultrasound image.

4. FUZZY C-MEANS CLUSTERING

The two-dimensional discrete wavelet transform with B-spline basis are used to decompose images into four frequency bands of LL, LH, HL, and HH. At the lowest level of decomposition, feature vectors based on the fuzzy c- means clustering algorithm are formed from HL, HH or LH, HH subbands. These high frequency subbands tend to amplify corresponding horizontal, vertical, and diagonal edges. Discrimination and classification of textures are implemented based on the reduced data set. Obviously, the benefit of this step is the direct reduction of computational complexity for the rest processing.

The fuzzy C-means clustering algorithm is applied for grouping together those pixels in the image, which have similar features in the feature space. The fuzzy *C*-means algorithm is based on minimization of the following objective function, with respect to *U*, a fuzzy *K*-partition of the data set, and to V, a set of K prototypes:

$$J_q(U,V) = \sum_{j=1}^{N}\sum_{i=1}^{K}((u_{ij})^q \bullet d^2(X_j,V_i)) \;\; ; \quad K \le N \qquad (1)$$

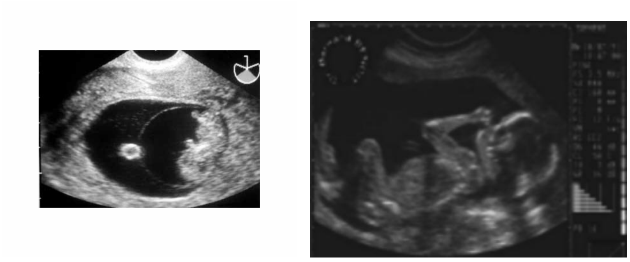
where q is the weighting exponent for uij and controls the "fuzziness" of the resulting clusters, and it is any real number greater than 1, Xj is the jth m-dimensional feature vector, Vi is the centroid of the ith cluster, uij is the degree of membership of Xj in the ith cluster, d2(Xj,Vi) is any inner product metric (distance between Xj and Vi), N is the number of data points, and K is number of clusters.

5. DATASET

10 ultrasound images for different ages of fetus have been segmented with the proposed algorithm. The system was implemented in VC++ on a windows 98 platform on PC PIII. Three radiologists have tested the performance of the system Experimental results demonstrate that the proposed technique is giving a comparable results to other technique.

6. EXPERIMENTAL RESULTS

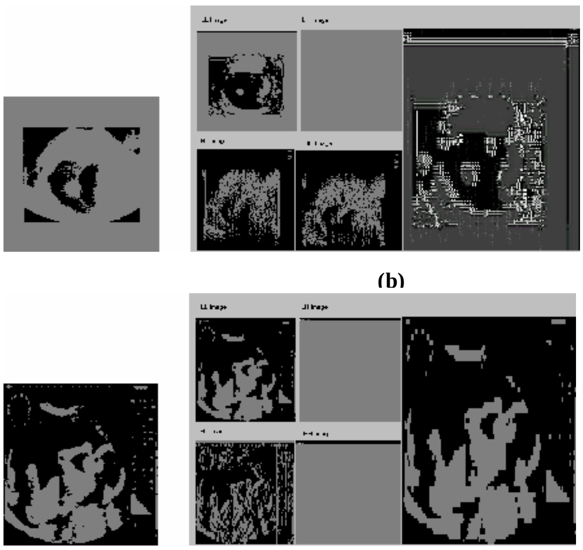
The preliminary testing of the proposed system was based on the digital ultrasound images shown in Fig. 4(a) and Fig. 4(b). These images are for 9 weeks and 22 weeks respectivly.



(a) **(b)**

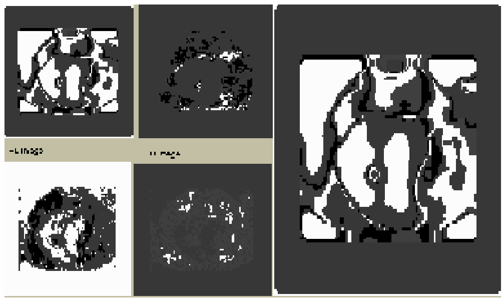
Fig.4. (a) Image 1 fetal ultrasound image 9 weeks. (b) Image 2 Original fetal ultrasound image 22 weeks.

These images are segmented using two methods: 1)fuzzy c-mean based on pixel gray level, 2) fuzzy c-mean based on fuzzy c-means texture feature, both methods in time domain and in wavelet domain. Fig. 5(a), 5(b) show the results for segmentation using the first method in time domain and in wavelet domain respectively for the original image Fig. 4(a). Also, Fig. 5(c), 5(d) The segmentation results for the original image in Fig 4(b). The second method results are demonstrated in Fig. 6 segmentation for 4 classes, and Fig. 7 segmentation for 2 classes. 6(a), 6(b) for the first image, also Fig. 6(c), 6(d) for the second image. In wavelet-based method the original image is decomposed using B-Spline wavelet transform. Then feature vector is built in the wavelet domain for every pixel that contains: mean, variance and one of the percentile. The fuzzy c-means clustering method segmented the image based on these information. Results shows that the method based on wavelet repersentation gives better segmentation results. The segmented fetus after the wavelet transform is more accurate than the the method based on gray level information only. Moreover the results of wavelet-based segmentation method gives less noise segmented image.

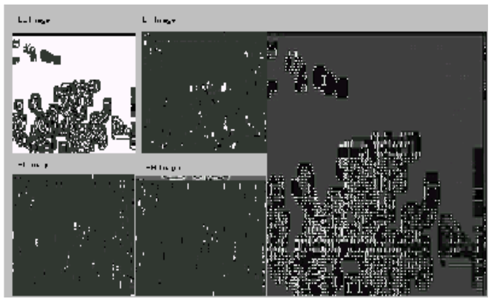


(c) **(d)**

Fig. 5. (a) Result after segmentation using Fuzzy C-Means technique (2 classes) based on pixels gray level for orignal image 1. (b) Resulted LL, LH, HL, HH, and reconstructed image 1 (by sizing) after segmentation using Fuzzy C-Means technique based on pixels gray level. (c) Result after segmentation using Fuzzy C-Means technique based on pixels gray level for orignal image 2. (d) Resulted LL, LH, HL, HH, and reconstructed image 2 (by sizing) after segmentation using Fuzzy C-Means technique based on pixels gray level.

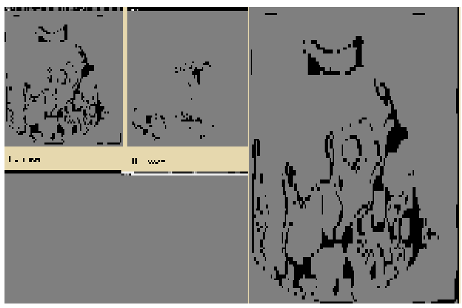


(a) **(b)**



(c) **(d)**

Fig. 6. (a) Result after segmentation using Fuzzy C-Means technique (4 classes) based on mean, variance, and percentile 30 texture feature vector for orignal image 1. (b) Resulted LL, LH, HL, HH, and reconstructed image 1 (by sizing) after segmentation using Fuzzy C-Means technique mean texture feature. (c) Result after segmentation using Fuzzy C-Means technique based on mean , variance, and percentile 30 texture feature vector for orignal image 2. (d) Resulted LL, LH, HL, HH, and reconstructed image 2 (by sizing) after segmentation using Fuzzy C-Means technique based on mean, variance, and percentile 30 texture feature vector.



(a) **(b)**

Fig. 7. (a) Result after segmentation using Fuzzy C-Means technique (2 classes) based on mean, variance, and percentile 30 texture feature vector for orignal image 2. (b) Resulted LL, LH, HL, HH, and reconstructed image 2 (by sizing) after segmentation using Fuzzy C-Means technique mean texture feature.

7. CONCLUSION

Previous studies suggested that wavelet-based image analysis techniques could occupy a leading position in medical imaging. the proposed approach to segment fetus ultrasound image was motivated by the ability of wavelets to discriminate diffetrent frequencies and to preserve signal details at different resolutions. However, the performance of the wavelet is affected by : 1) the properties of the wavelet filters used for subband image decomposition, 2) the intensity contrast between the background and tissue information, 3) the resolution of the original digital ultrasound image, 4) artifacts exist in the orignal images. This paper presented a novel method combining wavelet analysis and fuzzy c-means clustering method.

This work has focused on the algorithmic development and experimental justification.. more thorough theoretical analysis is expected in the future. The application of the wavelet transform to fetus segmentation is under our current investigation.

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