SEGMENTATION OF ULTRASOUND IMAGES BY USING AN INCREMENTAL SELF-ORGANIZED MAP

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Abstract-**This paper presents a new segmentation method for ultrasound images. A new incremental self–organized map is proposed for the segmentation of the ultrasound images. Elements of the feature vectors are formed by the fast Fourier transform (FFT) of image intensities in 4×4 square blocks.**

In this study, two neural networks for segmentation are comparatively examined: Kohonen map, and incremental self–organized map (ISOM). It is observed that ISOM gives the best classification performance with less number of nodes after a short training time.
Key words **- Self organized map, neural networks, segmentation of biomedical images, classification, multilayer perceptron.**

I. INTRODUCTION

The constitution of the right data space is a common problem in connection with classification. In order to construct realistic classifiers, the features that are sufficiently representative of the physical process must be searched. In the literature, it is observed that wavelet transform [1], co-occurence matrix [2], and Gabor transform [3] are used to extract features from images. These feature extraction methods increase the computational time of the classification process [4]. Previous studies showed that image intensities at one or two neighborhood of the pixel [5], or image intensities in multiple images (T1, T2 and proton density) can be utilized to represent the tissues in magnetic resonance images. However, it is not enough to use image intensities for representing the tissues in ultrasound images. In this study, feature vectors are formed by using the FFT.

There are many types of self-organizing networks applicable to a wide area of problems. One of the most basic schemes is competitive learning. The Kohonen network can be seen as an extension to the competitive learning network. A major advantage of the Kohonen network is its fast learning speed. The major disadvantages are: it is not an incremental network, and the network generates feature vectors throughout the inside of a class homogeneously rather then concentrating them on the boundaries between classes. This causes the generation of an excessive number of feature vectors. Another disadvantage is that a method for adapting the gain constant and the neighborhood parameter optimally during learning has not been developed.

In this study, 2D-FFT of image intensities in 4×4 square blocks are utilized to extract features from ultrasound images and a new incremental self–organized map is proposed for the segmentation of the ultrasound images.

II. METHODS

In the study, the ultrasound image is splitted into square blocks of 4×4 pixels, and 2D-FFT of each block is computed. 2D-FFT coefficients of a 4×4 block are shown in Fig. 1. In the proposed method, only four coefficients (F_{11}, F_{12}, F_{21} and F_{22}) which are shown inside a bold-bordered square are used to form the codewords.

The global scheme for the segmentation of the ultrasound images is described in Fig. 2. After vectorization (transformation of image blocks into vectors), the 2D-FFT coefficients are computed in the second stage to form codewords. Codeword vectors are formed by using the absolute values of the complex F_{ij} coefficients. In the third stage, the codewords are presented to an artificial neural network for the learning process. The proposed neural network generates a single index to label different tissues in the image. Lastly, the entire image is segmented by using the labels found during the learning.

III. ARTIFICIAL NEURAL NETWORKS

Classification performance highly decreases if the right feature space is not constituted. Artificial neural networks are used as classifiers to increase the classification performance. There are four reasons to use an artificial neural network as a classifier: 1) Weights representing the solution are found by iteratively training, 2) ANN has a simple structure for physical implementation, 3) ANN can easily map complex class distributions, 4) Generalization property of the ANN produces appropriate results for the input vectors that are not present in the training set.

In the literature, it is observed that new neural network structures have been investigated to increase the classification performances [5, 6]. In the study, two artificial neural networks are comparatively investigated for the segmentation of ultrasound images. These networks are the Kohonen network and the ISOM. The novel neural network structure is developed to increase the classification performance and to produce a solution to the problems mentioned in section 1.

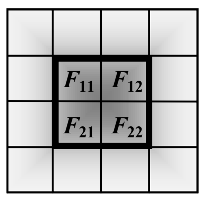

Fig. 1. Selected FFT coefficients for a block of 4×4 pixels.

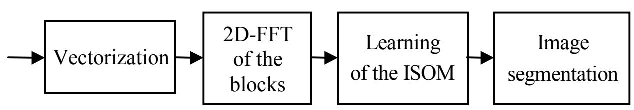

Fig. 2. Segmentation process.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Segmentation of Ultrasound Images by Using An Incremental Self-Organized Map	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Department of Electronics and Communication Engineering Istanbul Technical University Istanbul, Turkey	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
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A. Incremental Self-Organized Map

ISOM is a two-layer network shown in Fig. 3. In the figure, k represents the dimension of the codewords. The nodes in the first layer of ISOM represent the 2D-FFT coefficients vectors (codewords). The number of nodes in the first layer is automatically determined, and the nodes (codewords) are homogeneously distributed by the learning algorithm. The winner-take-all guarantees that there will be only one node activated. Index layer represents the index values of the codewords.

B. Learning of the ISOM

ISOM has incremental structure for unsupervised learning. The nodes in the first layer of the ISOM are formed by the codewords. Codewords are homogeneously distributed by testing the Euclidean distances between each other.

At the beginning, the codeword of the first square block is automatically selected as the first node of the ISOM. Then, the second square block is extracted from the image, and 2D-FFT coefficients of this block are computed. The distance between the codeword and the first node in the first layer of the ISOM is computed. If the distance is higher than the threshold determined previously, the codeword is assigned as a new node of the ISOM and a new index is assigned for this codeword. Otherwise, the third square block is extracted and search is continued until all square blocks in the image are exhausted.

The procedure for the learning algorithm of the ISOM is as follows:

Step 1: Extract a square block from the image in an order.
Step 2: Compute the 2D-FFT coefficients of the image in the square block to form a codeword.
Step 3: Compute the distances between the codeword and the nodes in the first layer, and find the minimum distance.
Step 4: If the minimum distance is higher than the threshold, include the codeword into the ISOM as a new node, increment the index counter by one, and assign the value in the counter as the index of the codeword.
Step 5: Go to step 1 until all square blocks in the image are exhausted.

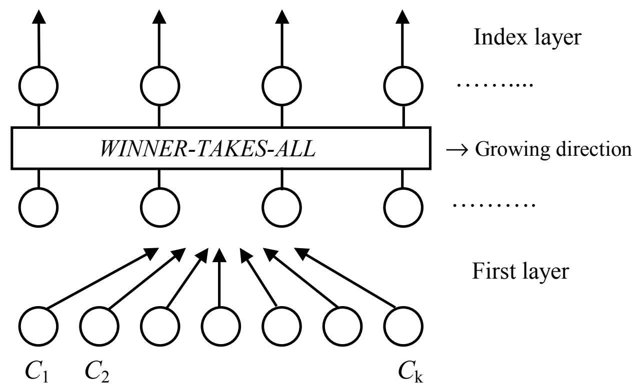


Fig. 3. Structure of the ISOM.

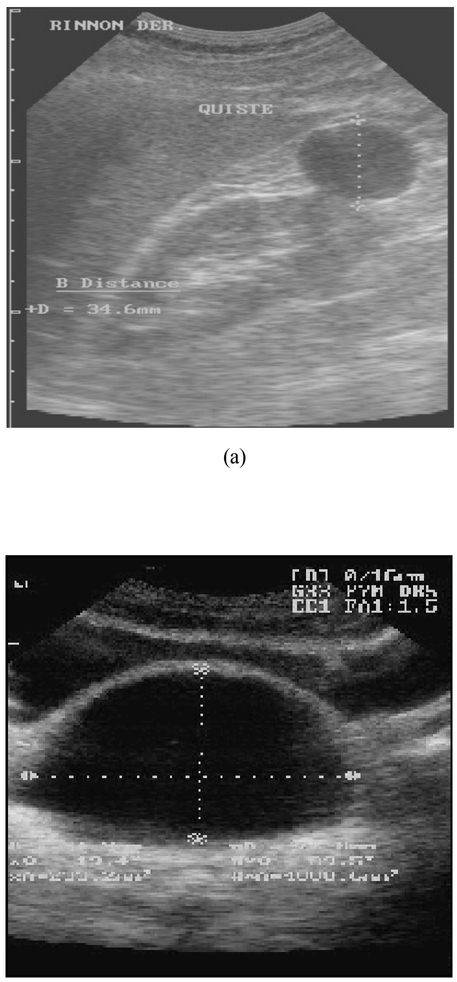
IV. Computer Simulations

In the study, two ultrasound images are segmented by using the ISOM and the Kohonen network. The ultrasound images of kidney cyst and bladder are shown in Figs. 4(a) and (b), respectively. All the simulations are performed on Pentium III-450 MHz PC using MATLAB 6.0.

The ultrasound images are splitted into square blocks of 4×4 pixels. Codewords are formed by using 2D-FFT of the square blocks. Training set consists of codewords formed by all the square blocks in the image.

The number of nodes in the first layer and the indexes of ISOM are automatically determined during the learning. Each index represents a different tissue in the image. Threshold value determines the number of classes (tissues) in the ultrasound images. In the study, thresholds for ultrasound images in Figs. 4(a) and (b) are selected as 60000 and 200000, respectively. Ultrasound images of kidney cyst and bladder in Figs. 4(a) and (b) are segmented into five and four tissues, respectively.

The numbers of nodes of the Kohonen network are estimated before the training. In the study, two different topologies of the Kohonen network are determined after 10 different trials with the same training set.



(a)

(b)

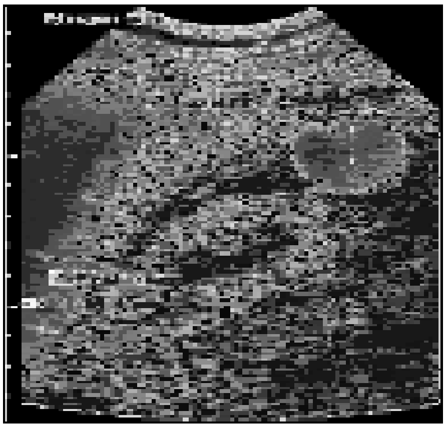
Fig. 4. Ultrasound images of (a) kidney cyst, and (b) bladder .

Figs. 5(a) and (b) show segmented ultrasound images by using the Kohonen network. Figs. 5(c) and (d) show segmented ultrasound images by using the ISOM.

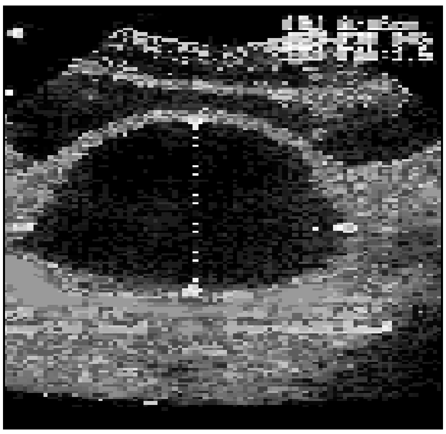
The number of nodes (NoN) generated, segmentation times (ST) of each ultrasound image, and training times (TT) of the Kohonen network and the ISOM are shown in Table I. It is observed that ISOM gives better classification results and has less number of nodes than the Kohonen network.

TABLE I
PERFORMANCES OF THE KOHONEN NETWORK (KN) AND THE ISOM

	Kidney cyst image		*Bladder image*	
	KN	ISOM	KN	ISOM
NoN	6×6	5	5×5	4
ST (sec.)	107.1	87.7	79.1	53.3
TT (sec.)	43.8	10.7	32.6	10.2

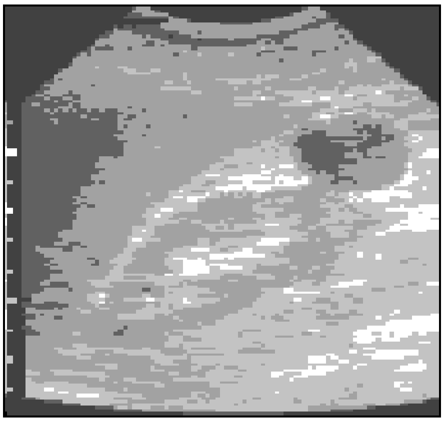


(a)



(b)

Fig. 5. (a) and (b) Segmented ultrasound images by the Kohonen network.



(c)

(d)

Fig. 5. (c) and (d) Segmented ultrasound images by the ISOM.

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