Ultrasound Pregnancy Images Classification Using Artificial Neural Network

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Abstract

This research introduces an automatic ultrasound human pregnancy images classification (male or female) system using artificial neural network to classify the pregnancy images. An automatic ultrasound human pregnancy images system consists of three Modules: The first is preprocessing ultrasound images (noise removing , image normalization and segmentation), second is feature extraction module then pregnancy classification module. After preprocessing, features extracting by using kernel principal component analysis (kernel PCA) after that, Elman neural network is used to a classify training and testing these pregnancy images. The system produces promising results for pregnancy images classification.

Keywords- Ultrasound images of human pregnancy, Feature extraction, Kernel principal component analysis (kernel PCA), Elman neural network, Artificial Neural Networks (ANN).

Introduction

It is often useful to have a machine perform pattern classification for medical images (analysis, processing and classifying the images), especially to classify ultrasound human pregnancy (male or female) images. Various techniques have incarnated as an unavoidable tool for the doctors to help them in diagnosis and generate very accurate results and very fast.One of these techniques is Artificial Neural Networks (ANN).Number of researches are proposed ANN method to automated classifying ultrasound images [2], The proposed method showed a good classification rate Kurtulus,1995 represent the features of blood velocity by wavelet coefficients, that are extracted the variations of blood velocity waveforms obtained from Doppler ultrasound images of fetal umbilical arteries. The obtained reliable features form the training samples of a classification algorithm to be used in intelligent diagnostic for fetal surveillance [8]. Ayache in 2009 and 2010 proposed an approach for classification of placental tissues development using ultrasound images. This approach was based on the selection of tissues, feature extraction by discrete wavelet transform and classification by neural network and especially the Multi Layer Perceptron (MLP). The proposed approach was tested for ultrasound placental images; resulting in 95% success rate. The method showed a good recognition for placental tissues and will be useful for detection of the placental anomalies those concerning the premature birth and the intrauterine growth retardation [2, 3]. ANN have been a natural choice as trainable pattern classifiers because of their capability to approximate functions and to generalize [1,5]. ANN is a powerful computational systems consisting of many simple processing elements connected together to perform tasks nalogously to biological brains. They are massively parallel, which makes them efficient, robust fault tolerant and noise independent [5, 15].The objective of this work is to create an automatic ultrasound human pregnancy images classification (male or female) depending on ultrasound human pregnancy images. We apply artificial Kernel principal component analysis (kernel PCA) as feature extraction and Elman artificial neural network technique to classify ultrasound human pregnancy images to male or female.

1- Automatic Ultrasound Human Pregnancy Images Classification System

2- The Automatic Ultrasound Human Pregnancy Images Classification System Consists Of Mainly Three Modules: Preprocessing Module Used To Enhance Ultrasound Images Of Human Pregnancy (Noise Removing, Normalization And Segmentation), Feature Extraction Module To Extracted Features From The Ultrasound Images After Preprocessed Using The Kernel Of Principal Component Analysis (Kernel Pca) and Ultrasound Human Pregnancy Images Classification Module to Differentiate Between Male or Female by Using Elman Artificial Neural Network, As Illustrated In Figure (1).

2.1 Preprocessing Operations

The Ultrasound images, see figure (2), are rarely of perfect quality. They may be degraded and corrupted due to image noise. Impression conditions and variations in the images. Thus, image enhancing techniques must be used prior to feature extraction, the preprocess module involves a series of image enhancement and steps that can be classified in three phases: Noise removal, Segmentation and Normalization for each of preprocessing phase’s steps.

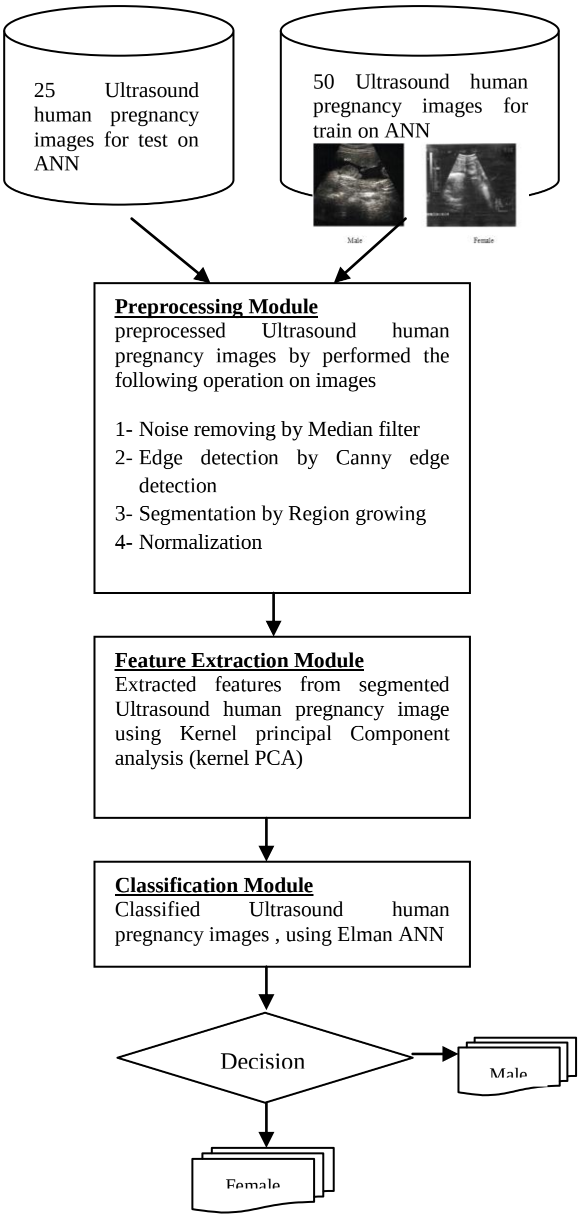


Figure 1. Automatic Ultrasound Human Pregnancy Images Classification (Male Or Female) System

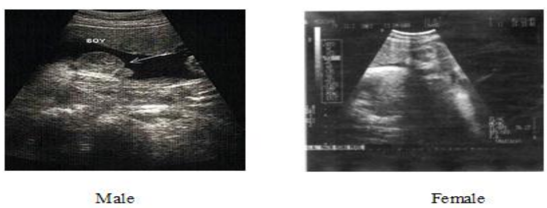


Figure 2. Ultrasound Human Pregnancy Images

2.1.1 Order Filter (Median) As Noise Removal

Medical images are usually corrupted by noise in its acquisition and Transmission. The main objective of image noise removal techniques is necessary to remove undesirable noises while retaining as much as possible the important signal features. Introductory section offer brief idea about different available noise removal schemes. Ultrasound imaging is a widely used medical imaging procedure because it is economical, comparatively safe, transferable, and adaptable. Though, one of its main shortcomings is the poor quality of images, which are affected by speckle noise [14]. In this research Median filter is used to remove noise from Ultrasound image. Median filter is a nonlinear digital filtering technique, often used to remove noise,it is used as typical pre-processing step to improve the results of later processing (noise removal and edge detection on an image), and it preserves edges whilst removing noise [17]. A median filter has three advantages: No reduction in contrast across steps, since the available output value consists only of those pixels present in the neighborhood. Median filtering does not shift boundaries, as can happens with conventional smoothing. Since the median is less sensitive than the mean to extreme values, those extreme values are more effectively removed [18]. In median filtering, the neighboring pixels are ranked according to brightness (intensity) and the median value becomes the new value for the central pixel. Median filters can do an excellent job of rejecting certain types of noise, in particular, “shot” or impulse noise in which some individual pixels have extreme values. In the median filtering operation, the pixel values in the neighborhood window are ranked according to intensity, and the middle value (the median) becomes the output value for the pixel under evaluation [18].

Algorithm : Median Filter [11]

Let $x_{i,j}$, for (i, j) ϵ A ≡ { 1, …, M} × (1, …, N, be the gray level of a true M-by-N image x at pixel location (i, j), and $[s_{min}, s_{max}]$ be the dynamic range of x, i.e. $s_{min} \le x_{i,j} \le s_{max}$ for all (i, j) ϵ A. Denote by y a noisy image. In the classical noise model, the observed gray level at pixel location (i, j) is given by

$$y_{i,j} = \begin{cases} smin, \text{ with probabili} \\ smax, \text{ with probabili} \\ x_{ij} \text{ with probability } 1 \end{cases}$$

where r = p+q defines the noise level. Here we give a brief review of the filter. Let be a window of size w × w centered at (i, j), i.e.

= {(k, l) : | k – I| ≤ w and |j-l} ≤ w}

and let $w_{max} \times w_{max}$ be the maximum window size. The algorithm tries to identify the noise candidates $y_{i,j}$, and then replace each $y_{i,j}$ by the median of the pixels in $S_{i,j}^{w}$ [4,9]. For each pixel location (*i; j*), do

1. Initialize type equation here. *w* = 3.

2.Compute $S_{i,j}^{\min,w}, S_{i,j}^{med,w}, S_{i,j}^{\max,w}$, which are the minmum, median and maximum of the pixel values in $S_{i,j}^{w}$ respectively.

3. If $S_{i,j}^{\min,w} < S_{i,j}^{med,w} < S_{i,j}^{\max,w}$, then go to step 5. Otherwise, set w=w+2.

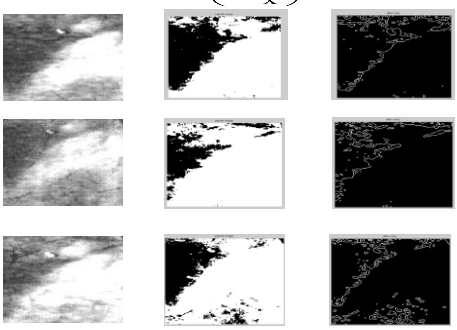
4. If $w \le w_{max}$ go to step 2. Otherwise, we replace $y_{i,j}$ by $S_{i,j}^{med,w\max}$

$S_{i,j}^{med,w}$ 5. If $S_{i,j}^{\min,w} < y_{i,j} < S_{i,j}^{\max,w}$, then $y_{i,j}$ is not noise candidate. Else we replace $y_{i,j}$ by

$S_{i,j}^{med,w}$ The adaptive structure of the filter ensures that most of the impulse noises are detected even those at a high noise level provided that the window size is large enough. Notice that while the remaining pixels are left unaltered. After noise are removed by using median filtering, Canny edge detection is used to detected edges in ultrasound images. Canny uses a multi-stage algorithm to detect a wide range of edges in images. Canny's aim to discover the optimal edge detection algorithm. In this situation, an "optimal" edge detector means good detection, good localization and minimal response stages of the Canny algorithm [4, 19]. Canny algorithm uses four filters to detect horizontal, vertical and diagonal edges in the blurred image. The edge detection operator (Roberts, Prewitt, Sobel) returns a value for the first derivative in the horizontal direction (Gy) and the vertical direction (Gx). From this the edge gradient and direction can be determined, see figure (3) [4, 19]:

$$G = \sqrt{G_x^2 + G_y^2} \quad \text{….. (1)}$$

$$\theta = \arctan\left(\frac{G_y}{G_x}\right) \quad \text{….. (2)}$$



Original after median filter after Canny filter

Figure ٣. Canny Filter on Ultrasound Images

2.1.2Segmentation

In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels) . The goal of segmentation is to simplify an image into aform that is more meaningful and easier to analyze [9, 20].Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region are similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s) [9, 20]. In this research Region growing methods have been used to segment images. Because the region growing methods can correctly separate the regions that have the same properties, region growing methods can produce good segmentation results. A small numbers of seed points are required to represent the wanted property, then grow the region. Seed points were determined and the criteria have been made, multiple criteria chooses at the same time and it performs well with respect to noise. Region growing is one of the simplest region-based image segmentation methods and it can also be classified as one of the pixel-based image segmentations because it involves the selection of initial seed points [21]. This approach of segmentation examines the neighboring pixels of the initial "seed points" and determines if the pixel should be added to the seed point or not. The process is iterated as same as data clustering. Some segmentation methods such as "Thresholding", achieve the goal by looking for the boundaries between regions based on discontinuities in gray levels or color properties, while region-based segmentation defines the region directly, as described below [6, 21]:

(a) $\bigcup_{i=1}^{n} R_i = R$

(b) R_i is a connected region, i = 1, 2, ...,n

(c) $R_i \cap R_j = \varnothing$ for all i = 1,2,...,n.

(d) $P(R_i)$ = TRUE for i = 1,2,...,n.

(e) $P(R_i \cup R_j)$ = FALSE for any adjacent region R_i and R_j .

where $P(R_i)$ is a logical predicate defined over the points in set $P(R_k)$ and Ø is the null set.

(a) Indicates that the segmentation must be complete; that is, every pixel must be in a region.

(b) Requires that points in a region must be connected in some predefined sense.

(c) Indicates that the regions must be disjoint.

(d) Deals with the properties that must be satisfied by the pixels in a segmented region-for example R_i = TRUE if all pixels in R_i have the same gray level.

(e) Indicates that region R_i and R_j are different in the sense of predicate P .

2.1.3 Normalization

The image must be normalized after segmentation to size (256 , 256) pixels, so that it has prespecified mean and variance. This results in a maximum span of the grayscale variation in the image, with the help of spreading the histogram of the image across the entire spectrum. This is done by analyzing minimum and maximum values of the image [7] .

$$I_{prep}(x, y) = \frac{I(x, y) - \min(I)}{\max(I) - \min(I)} \quad \text{…. (3)}$$

with I being the input image pixel values and

$$I_{prep} \in [0,1]$$

2.2 Feature Extraction Module

In pattern classification and in image processing, Feature extraction is a special form of dimensionality reduction. When the input data to an algorithm is too large to be processed and it is suspected to be notoriously redundant (much data, but not much information) then the input data will be transformed into a reduced representation set of features (also named features vector). Transforming the input data into the set of features is called features extraction. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input. Best results are achieved when an expert constructs a set of application-dependent features. Nevertheless, if no such expert knowledge is available general dimensionality reduction techniques may help. These include Principal components analysis, Kernel principal component analysis [22]. Kernel principal component analysis (kernel PCA) are used to reduced segmented image (256 , 256) pixels to 3 kernel PCA values. kernel PCA is an extension of principal component analysis (PCA) using techniques of kernel methods. Recall that conventional PCA operates on zero-centered data; that is[12,23]

$$\sum_{i=1}^{N} x_i = 0 \quad ..(4)$$

it operates by diagonalizing the covariance matrix,

$$\frac{1}{N}\sum_{i=1}^{N} x_i x_i^T \quad ..(5)$$

in other words, it gives an eigen decomposition of the covariance matrix [23]:

$$\lambda v = Cv \quad ..(6)$$

which can be rewritten as

$$\lambda x_i^T v = x_i^T C v \qquad \forall i \in [1, N] \quad ..(7)$$

To understand the utility of kernel PCA, particularly for clustering, observe that, while *N* points cannot in general be Elmanly separated in $d < N$ dimensions, but can almost always be Elmanly separated in $d \geq N$ dimensions. That is, if we have *N* points, $\mathbf{x}_i$, if we can map them to an *N*-dimensional space with

$$\Phi(x_i)=\delta_{ij} \quad ..(8)$$

where $\Phi: R^d \longrightarrow R^N$ and δ_{ij} is the Kronecker delta. It is easy to construct a hyperplane that divides the points into arbitrary clusters. Of course, this Φ creates Elmanly independent vectors, so there is no covariance. In kernel PCA, a non-trivial Φ function is chosen so that the points $\Phi(x_i)$ are not independent in R^N. And instead of choosing Φ explicitly, we choose .

$$K = k(x,y) = (\Phi(x),\Phi(y)) \quad \ldots (9)$$

where K is the Gramian matrix in the high-dimensional space. Kernel PCA allows us to operate in such a space without explicitly mapping the data into the high-dimensional space. Because PCA can be cast as an optimization problem in terms of inner products with the transposed data matrix,

$$v_1 = \underset{\|v\|=1}{\arg\max}\ \mathrm{var}\{v^T x\} = \underset{\|v\|=1}{\arg\max}\ E\{(v^T x)^2\} \quad ..(10)$$

We just need to compute inner products in the high-dimensional space. This is the purpose of the kernel [12].

2.3 Classification Module (Elman Artificial Neural Network)

The classifier module in an automatic ultrasound human pregnancy images classification (male Or female) system is Elman neural network , the three kernel PCA values are used as input to Elman neural network to classify pregnancy images as male or female. With the aim of simulating the operation of the human brain Artificial Neural Networks (NNs) has been adopted in pattern recognition problems such as classification mainly because of their flexibility and adaptability to environmental changes [10]. Artificial Neural Network(ANN) has the ability of large scale computing and has advantages when dealing with nonlinear high dimensional data [13]. ANNs are intelligent tools for recognized complex patterns, They also have excellent training capabilities which are often used in complex problems. Elman neural network is a kind of feedback neural network that is to add a connecting layer to the hidden layer of feed-forward network as time delay operator so as to memorize and therefore, makes the system have the characteristic of time-varying and have stronger global stability, see figure 4, [13].

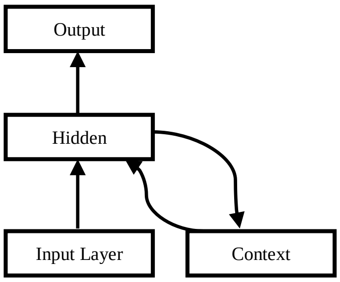


Figure 4. The Elman Neural network Architecture [10]

Topology of Elman recurrent neural network is shown in figure 5, in which the topology structure can be devided into four layers namely inpur layer, hidden layer, connecting layer and output layer. Connecting layer is used to memorize the output of the former moment from the hidden layer unit and can be regarded as a one-step time delay oprator. On the basis of the basic structure of BP neural network, the output of hidden layer is linked to the input of itself by the delay and storage of the output of hidden layer, which makes it sensitive to the data in historical states. The addition of interior feedback network increases the capability of processing dynamic information of the network itself. Storing the interior states makes it have the function of mapping dynamicity, and therefore makes the system have the ability to adapt to time-varying characteristics [13]. Suppose there are *n* inputs, *m* outputs and *r* neurons in hidden layer and connecting layer, the weight from input layer to hidden layer is w_1, while the weight between connecting layer and hidden layer is w_2 and the weight from hidden layer to output layer is w_3, $u(k\text{-}1)$ represents the inputs of the neural network, $x(k)$ represents the outputs of the hidden layer, $x_c(k)$ represents the outputs of the connecting layer, and $y(k)$ represents the outputs of neural network [13]. Then

$$x(k) = f(w_2 x_c(k) + w_1(u(k-1))) \quad ..(11)$$

$$x_c(k) = x(k-1) \quad ..(12)$$

$$y(k) = g(w_3 x(k)) \quad ..(13)$$

in which *f* represents the transfer function of hidden layer. *S* type function is commonly used and can be defined as

$$f(x) = (1 + e^{-x})^{-1} \quad ..(14)$$

g is the transfer function of the output layer and it is usually a linear function.

Elman network uses BP algorithm to modify the weight values and the error of the network is:

$$E= \sum_{k=1}^{m} (t_k - y_k)^2 \quad ..(15)$$

in which t_k is the output vectors of the object . Input Layer Hidden Layer Output Layer

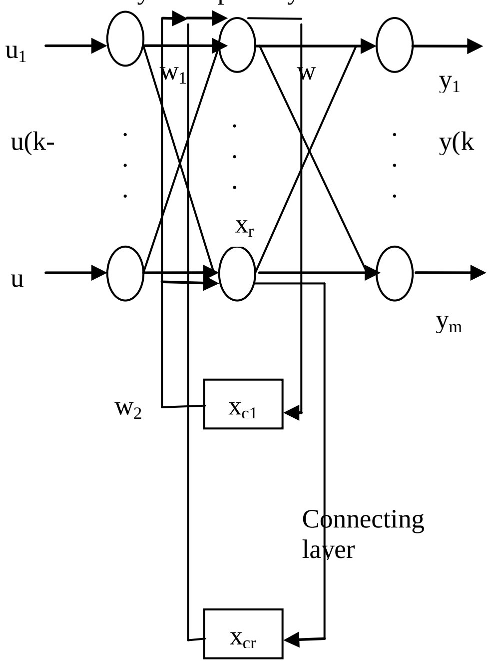


Figure 5. Topology Structure of Elman Neural Network [13]

Training an Elman Network

Train an Elman network the following occurs [16, 24] : At each epoch,

1. The entire input sequence is presented to the network, and its outputs are calculated and compared with the target sequence to generate an error sequence.
2. For each time step, the error is back propagated to find gradients of errors for each weight and bias. This gradient is actually an approximation, because the contributions of weights and biases to errors via the delayed recurrent connection are ignored.
3. This gradient is then used to update the weights with the chosen backprop training function.
4.Input vectors are presented to the network, and it generates an error.
5.The error is backpropagated to find gradients of errors for each weight and bias. This gradient is actually an approximation, because the contributions of weights and biases to the error, via the delayed recurrent connection, are ignored.
6. This approximate gradient is then used to update the weights with the chosen learning function.

3.Experiment Resultsw

used Elamn neural network for training and testing classification of Ultrasound Pregnancy Images to male or female. 75 Ultrasound Pregnancy images (Male or female with ages 16 – 36 weeks) taken from Ibn Sena Teaching hospital - Mosul/Iraq, and from internet [25] divided these images as 50 images for training on Elman neural network, and 25 images for testing. The purpose of the experiment is to evaluate the performance of the Ultrasound Pregnancy Images classification system by applying the noise remove techniques (Median filter), detection edges by(Canny detection) and segmentation using region growing on the human Pregnancy Images. Kernel principal component analysis are used to reduced segmented image after normalized from (256 , 256) to 3 kernel PCA values, See table (1).

Table 1. 3 kernel PCA Values for Ultrasound Pregnancy Image

No.	Images	3 Kernel PCA Values		
1		-0.0491	0.0281	-0.0301
2		-0.0466	0.1243	0.0665
3		-0.1324	0.0396	0.0363

Kernel principal component analysis dose extract features which are more useful for classification Ultrasound Pregnancy Image. Elman neural network was built as shown in figure (6) using Matlab (R2009a)[16] , with the kernel PCA values taken as input values. The structure of Elman neural network used in Ultrasound Pregnancy Image classification system consist of, see figure 6, 3 input nodes (u1,u2,u3), 2 hidden nodes and 1 output node (y1), number of epoch for training is 4000, learning rate = 0.9. `The result of classification of training on 50 Ultrasound Pregnancy Image are 100% and result of classification of testing on 25 Ultrasound Pregnancy Image are 96.1%.

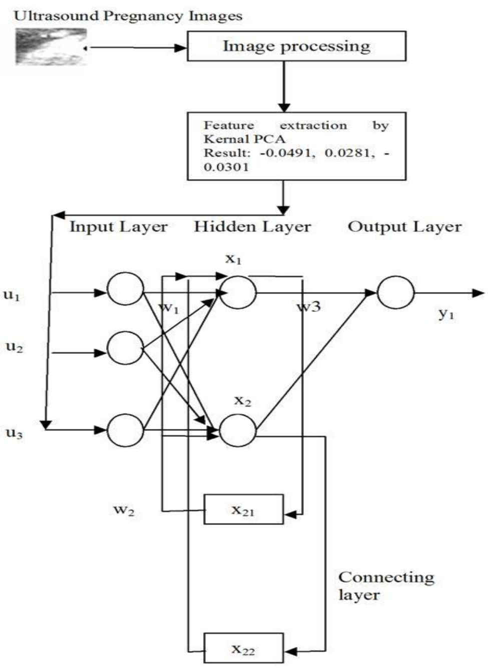


Figure 6. Automatic Ultrasound Human Pregnancy Image (Elman Neural Network Classification) System

Proposed Ultrasound Pregnancy human Images system has a high classification rate when the classification rate compared with another system. Ultrasound Pregnancy human Images system executed on the same database used in [1] with 75 Ultrasound Pregnancy images database (Male or female with ages 16 – 36 weeks) taken from Ibn Sena Teaching hospital - Mosul/Iraq, and from internet [25]. The classification rate on training database is 100% and in [1] is 99.78% and the classification rate on testing database is 96.1% and it is higher than in [1] where the classification rate is 92%, see table [2] and figure 7.

Table2. Compared the Proposed Ultrasound Pregnancy Human Images System with Previous Research

Database: 75 Ultrasound Pregnancy images (Male or female with ages 16 – 36 weeks) taken from Ibn Sena Teaching hospital - Mosul/Iraq, and from internet [25] divided these images as 50 images for training on neural network, and 25 images for testing			
System	Training classification rate	Testing Classification rate	ANN
Alzobaidy L.M (2009) (li	99.78%	92%	Linear
Proposed Ultrasound Pregnancy human Images system	100%	96.1%	Elman

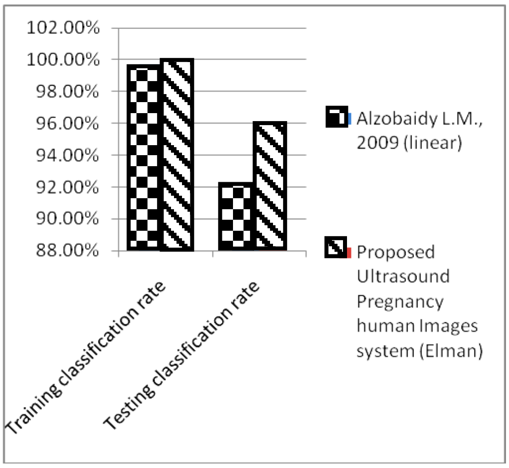


Figure 7. Compared the Proposed Ultrasound Pregnancy Human Images System with Previous Research

4.Conclusion

In this research a novel Ultrasound Pregnancy human Images system using artificial neural networks is presented. The experimental results show that classification rate 100% of training on 50 Ultrasound Pregnancy images and Classification rate 96.1% of testing on 25 Pregnancy human Images by using Kernal PCA and Elman neural network classifier gives the highest accuracy classification rate.

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تصنيف صور الاشعة الفوق الصوتية للحمل باستخدام شبكة عصبية اصطناعية

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الملخص :

يقدم هذا البحث نظام آلي لتصنيف صور الحمل للجنس البشري (ذكر او انثى) باستخدام شبكة عصبية اصطناعية لتصنيف صور الحمل . النظام الآلي للأشعة الفوق الصوتية لصور الحمل الانساني يتكون من ثلاث وحدات : الوحدة الاولى هي معالجة اولية لصور الاشعة الفوق الصوتية (ازالة الضوضاء ، تطبيع وتقطيع) والثانية استخلاص الخواص والاخيرة تصنيف صور الحمل .بعد المعالجة الاولية لصور الاشعة الفوق الصوتية يتم استخلاص الخواص باستخدام تحليل مركبة النواة الأساسية (kernel PCA) بعد ذلك ، استخدام شبكة ايلمان العصبية الاصطناعية لتصنيف وتدريب واختبار هذه الصور. يقدم النظام نتائج واعدة لتصنيف صور الحمل .