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Comparing diagnosis of depression in depressed patients by EEG, based on two algorithms: Artificial nerve networks and neuro-fuzzy networks

Babak Mohammadzadeh[1*], Mehdi Khodabandelu[1], Masoud Lotfizadeh[2]
[1]*Clinical Psychologist, Tabriz, I.R. Iran;* [2]*Social Health Determinants Research Center, Shahrekord University of Medical Sciences, Shahrekord, I.R. Iran.*
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ABSTRACT

Background and aims: Depression disorder is one of the most common diseases, but the diagnosis is widely complicated and controversial because of interventions, overlapping and confusing nature of the disease. So, keeping previous patients' profile seems effective for diagnosis and treatment of present patients. Use of this memory is latent in synthetic neuro-fuzzy algorithm. Present article introduces two neuro-fuzzy and artificial neural network algorithms as an aid for psychologists and psychiatrists to diagnose and treat depression.

Methods: Neuro-fuzzy has been carried out using data evaluated by psychiatrists and scholars in Tabriz city with the convenience sampling method. Sixty-five patients were studied from whom 40 patients were taught feed forward, back propagation by artificial neural network algorithm and 14 patients were tested. An inductive neuro-fuzzy intervention created neuro-fuzzy rules to decide about depression diagnosis.

Results: The proposed neuro-fuzzy model created better classifications. Reaching maximum accuracy of 13.97%is appropriate in diagnosis prediction. The results of the present study indicated that neuro-fuzzy is more powerful than artificial neural network with accuracy 76.88%.

Conclusion: Findings of the research showed the depression scores of beck inventory can be predicted and explained with the accuracy of 87% using EEG in F4 and alpha peak frequency. It can be said that such accuracy in predicting can't be obtained by any regression or route analysis method. The research can be the first step to predict and even identify depression using taking the data directly from the brain. So, there is no need for inventory and even a specialist diagnosis.

Keywords: Depression disorder, Neuro-fuzzy, Artificial neural network, Depression prediction.

Original article

INTRODUCTION

Depression is the most common disease of our era, but it is increasingly growing all over the world. Depression is not a special disease, but it emerges in all ages, races, as well as in men and women. Depression emerges in several forms. It also has several

[*]**Corresponding author:**Babak Mohammadzadeh, Clinical Psychologist, Tabriz, I.R. Iran, Tel: 00989142470271, E-mail: babak2000_m@yahoo.com

causes. Any form of depression has also some types. Even people who seem to suffer from a similar type of depression, their disease may be different slightly from each other. Therefore, depression is not a simple variable, but it is a complicate and multi-dimensional phenomenon.

Based on the guiding criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) a depressed person must have the following status: hopelessness and sadness. A depressed person feels dull and can't decide or start an activity or being interested in something. Such a person feels incapability and worthless, thinks about his/her defeats and fails, and maybe plan about suicide. Hyper and hypo- somnia, anorexia, gloominess, heart beating, peevishness, visual impairment, confusion, oral dryness, nausea, restlessness, and decreased libido are some signs of depression.

Evaluation, diagnosis, and prognosis of depression are so important and of course difficult issues in this regard. The traditional psychological researches have been based on the main statistical methods in the measurement and prognosis of depression according to the regression and route analysis. Although the used methods have been helpful, they have some fundamental problems. The first problem is their linearity since they follow the complex patterns. Most researchers have tried to excessive, artificial, and unreal simplify of these complicated patterns and have attempted to explain and predict the humanity variables such as depression and his/her positive or negative behavior Achen.[1] The second problem is the complex nature of the effective and predictive variables. Regression and the route analysis have some limits in measuring the variable number and their relationship. So that if the number of predictor variables is high, the error will be increased abnormally and the model will be an inefficient one Beek.[2] The 2 problems, linearity and variables limit, cause the decrease of accuracy of these kind of models, so they can't obtain an accurate statistic about the real world. Therefore, the use of new and complex methods which harmonize with the psychological complex variables' nature seems necessary. One of the successful methods in different scientific areas is the Artificial Neural Network (ANN) that advanced and compound form is the Artificial Neural-Fuzzy Network. These networks don't need predetermined especial data, such as probability distribution function or the relationship among variables such as regression and route analysis. They are compatible with the nonlinear and nonparametric patterns and can process many predictive and predictor variables concurrently. They have also the capability of learning. These characteristics make them the strong networks for identification and classification of complex patterns such as depression pattern. In the use of artificial neural network, the relationship among variables may be discovered by some of their models even if their complexity and used for future predictions.

In the recent years some researchers have been attracted by this approach. Marks introduced a computerized system for phobic, panic, stress, obsession, and depression, which aimed to decrease the time spent by clinicians.[3] Razzouk reported a case study for modeling the diagnosis of schizophrenia and psychotic disorders.[4] Milla published a framework depended on fuzzy abnormal signs for modeling the inaccuracy and evaluation of depression. Begum extended a framework for diagnosis people stress using finger temperature.[5] Palanivel explained a neural method.[6]In that method a radial basic function (RBF) and Back propagation were used which demonstrated high accuracy in identifying the psychological problems, but study about its mechanism has explained a little about

the method. Ariyanti reported a fuzzy system in which he merged 21 testing question back 2.[7]

Most researches have been conducted on the relationship between depression and brain function. One of the most frequent findings is typically the involving of dorso-lateral pre-frontal cortex shortly DLPFC (Nitsche).[8] According to the findings, in depressed people the activity and neural firing of this region increases in right and decreases in left hemispheres. If the activity of this region is measured by QEEG, the increased level of alpha wave (8-12 Hz) in the right hemisphere and its decreased level in the left one as well as DLPFC region will be observed (Alpha wave power has an inverse relationship with the function level of a region). Furthermore, the feedback of the region in depressed and healthy people in response to the different stimulations is different. The depressed people demonstrate greater activity in DLPFC in response to an image or Scene and their alpha wave power will be decreased, while the left hemisphere's function is inversely. In the response to a positive or happy scene the normal people have greater activity in the left DLPFC and alpha wave power decreases in this region, while the right side functions inversely (Boggio).[9]

The mentioned findings demonstrate that the brain process can be understandable in confronting with positive and negative emotional stimuli probably by recording the brain activity only in one region.

In this study, we attempted to go a step further and obtain an accurate estimate based on depression scores of a person in Beck Depression Test and depression signs.

METHODS

This study is considered a simulation and modeling one. The research tools in our study comprised of Procomp infinity device to take EEG and Beck Depression inventory, two methods including Artificial neural network (ANN) and Logical Neural-Fuzzy system which will be explained in the following:

Beck's depression inventory 2 (BDI-II): Is composed of 21 questions and the responses scored between 0 and 3.[10]The inventory has a 71% correlation with Hamilton's depression score scale. It's one week interval of retesting reliability is 93%.

EEG device: in this research a Procomp 2 device made by Tought Technology Co. With two canals and frequency range of 0.5 to 40 Hz, was used. A sampling rate of 8 Hz and single-canal recording on point F4 of the brain were used as well.

The general method of the research has been demonstrated in figure 1. The system has been implemented using data evaluated by psychiatrists and scholars in Tabriz city with convenience sampling method. 65 patients were studied from whom 50 patients were taught feed forward, back propagation by artificial neural network algorithm and 15 patients were tested. After the introduction and explanation the test process, the Beck test conducted on the subjects to assess baseline Depression. Neuro-feedback device (Procomp2 Infinity) was used to extract the traits from EEG as a device that displayed fife images selected from emotional images of global database to the user, and the EEG was recorded, concurrently. The necessary changes have been previously applied to fit its hardware and software to the researcher's test. IAPS is a global database of emotional pictures on the web belonging to the University of California that has classified the images according to their emotional excitation power.5 photos from5different categories and different emotional conditions were selected by researcher and a40-second film was made of them.

Each image displayed for5seconds,then a neutral image for 3 seconds and again the next image until the end of the displaying. Finally, the individual EEG was recorded.

Table 1: The displayed Images and their IAPS number: Selected images from the IAPS global database and their properties

1	2	3	4	5
Fear	**Entertainment**	**Nature**	**Satisfaction**	**Disgust**
				
Angry snake International IAPS No. 1052	Happy Cats International IAPS No. 1463	Fishin the ocean International IAPS No. 1900	Happychild International IAPS No. 2058	Flyon the cake International IAPS No. 7360

The input of these two model includes 5 extracted characteristic from EEG recorded from F4 point of the brain of patients with depression which is called $\alpha_{peakfrequancy}$ to 5-bits pieces of α^{1}_{peak}, α^{2}_{peak}, α^{3}_{peak}, α^{4}_{peak} and α^{5}_{peak}. The point, that is F4 andα_{peak} was selected according tothe previous studies.[11,12]The data gathering screen which was conducted in Procomp Infinity (feedback device) is observed in picture 3. On the right side a film of 5 pictures is displayed and was seen via monitors in front of the subjects. In the left side the EEG and the Alpha peak diagram are seen. After the recording process from the Export Data menu the Alpha peak of EEG is extracted. In fact, at this stage the analogues are changed to digital data.

In compliance with the professional ethics in Referrals as well as at the top ofthe Beck questionnaire that was provided to patients, assured them that no electricity entered their body through the use of ProComm device electrode. Also a written consent was received from each subject to conduct the test and published the results.

ANN and Logical Fuzzy system are the 2 methods of the research. The classification among evaluation and educational groups was conducted randomly and 70% was selected for model education and 30% for evaluation.

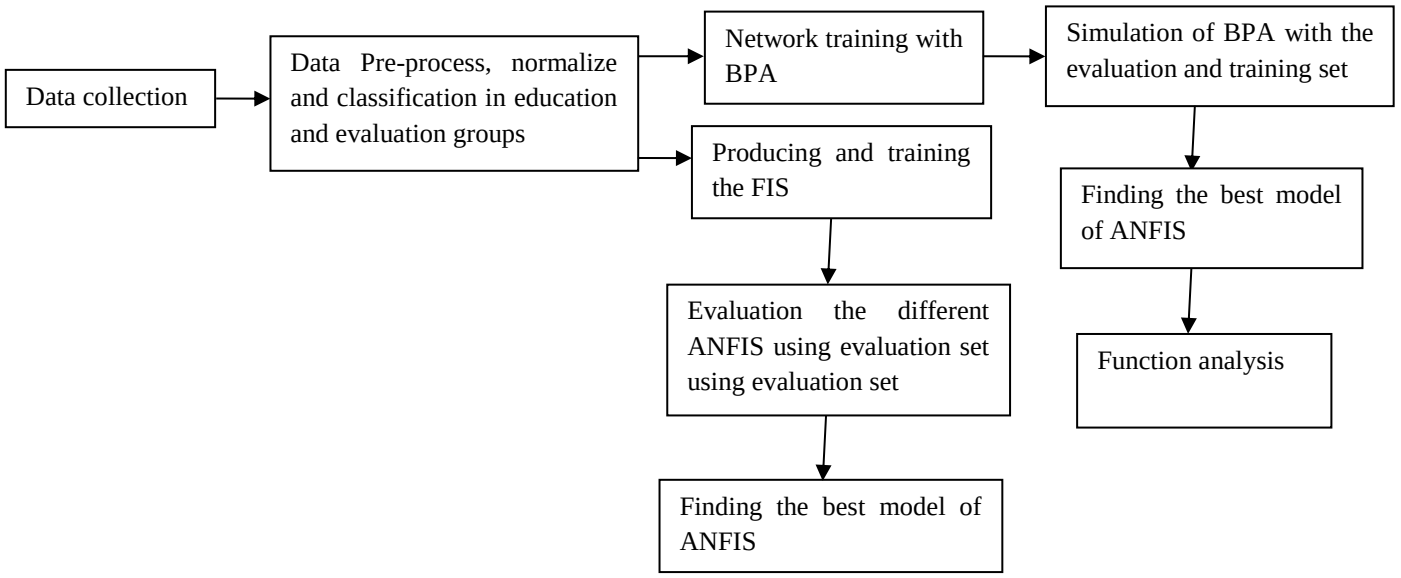

Figure 1: The architecture of ANFIS

The algorithm (Fitnet) which is used for ANN was Back propagation (trainlm) that uses a descent gradient to minimize the output error in a two-layer feed forward network. Therefore, it uses a controlled learning to teach the network, which has the latent layer sigmoid neurons and linear output neurons.

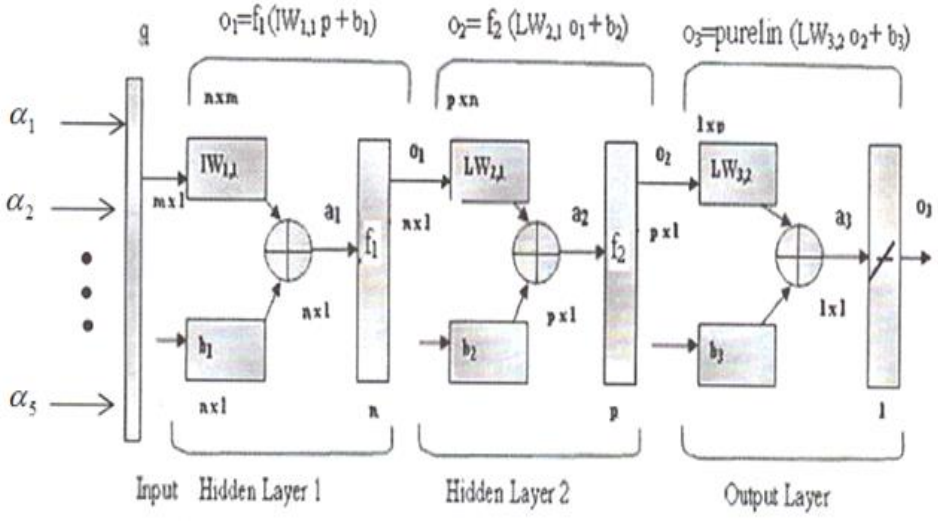

Figure 2: A three-layer neural network

Fuzzy logic (FL) provides a tool to manipulate the inaccurate but logical data. The Fuzzy logic theory explains the mathematics powerful fundamentals to principled combine the unreliability which emerged in human cognitive processes.

The soft calculations are methodologies to obtain the possibility to resolve the real world problems which resulted by different carelessness and unreliability. The basic samples of the soft calculation include ANN, FL, and the Genetic Algorithm (GA). Each of the samples has its own weak and strength points as well as its own limits. For example, the most important priority of fuzzy systems is their simplicity and clarity in explaining of IF THEN fuzzy principles, but the ANN is not learned in this method. ANN, in turn, suffers from lack of clarity in the extracted knowledge from data processing and learning stages. The combined model, neural-fuzzy, resolves the limit of fuzzy system education and the lack of clarity of the neural network.

The Fuzzy derivation process composed of five parts:

a. Fuzzification of input variables: It means to receive the inputs and determine the membership grade to fuzzy contents using membership functions. The output of this phase is a fuzzy degree which determines the level of input membership. This output is usually a digit between 0-1.

b. Applying Booleans (And-Or): Following the input fuzzification, the degree of accuracy of any data component has been determined. If the hypothesis part has different parts, the fuzzy operators were used to combine the accuracy degree of the parts and produce a digit accuracy degree on hypothesis part. The resultant digit of this process is the output function.

c. Implication the hypothesis to the result: It involves the methods used to apply. It includes the minimum which cuts the output fuzzy set, and Prod (multiplying) which scales the output fuzzy set.

d. Output aggregation: Three methods are used to aggregate: maximum, probor, and sum. With this compound the output is converted to a unified fuzzy set.

e. Defuzzification: The input of this phase is a fuzzy set and its output is a digit. This method is the most popular of defuzzification to calculate the center of gravity. The start point of forming a fuzzy system is obtaining a set of fuzzy If-Then principles using a skilled person's knowledge of the knowledge of the considered area. A method to use digit information to produce a logical fuzzy principle is a very important tool. Another new method for modeling is ANN that the most important reason of their powerfulness is their educability (proportional inputs and outputs) using different algorithms of education which identifies accordingly the relationship between input and output variables. The preliminary plan of these models has been based on the learning model of the human neural system. The term ANFIS is the abbreviation of Adaptive Nero Fuzzy Inference System, which has been widely used to examine the nonlinear equations. So, the combination of fuzzy systems which are based on the logical principles, as well as ANN which are able to extract knowledge from the digit data, enable us to use other information along with human knowledge to produce a model. The presented method on this base is the Adaptive Nero Fuzzy Inference System.

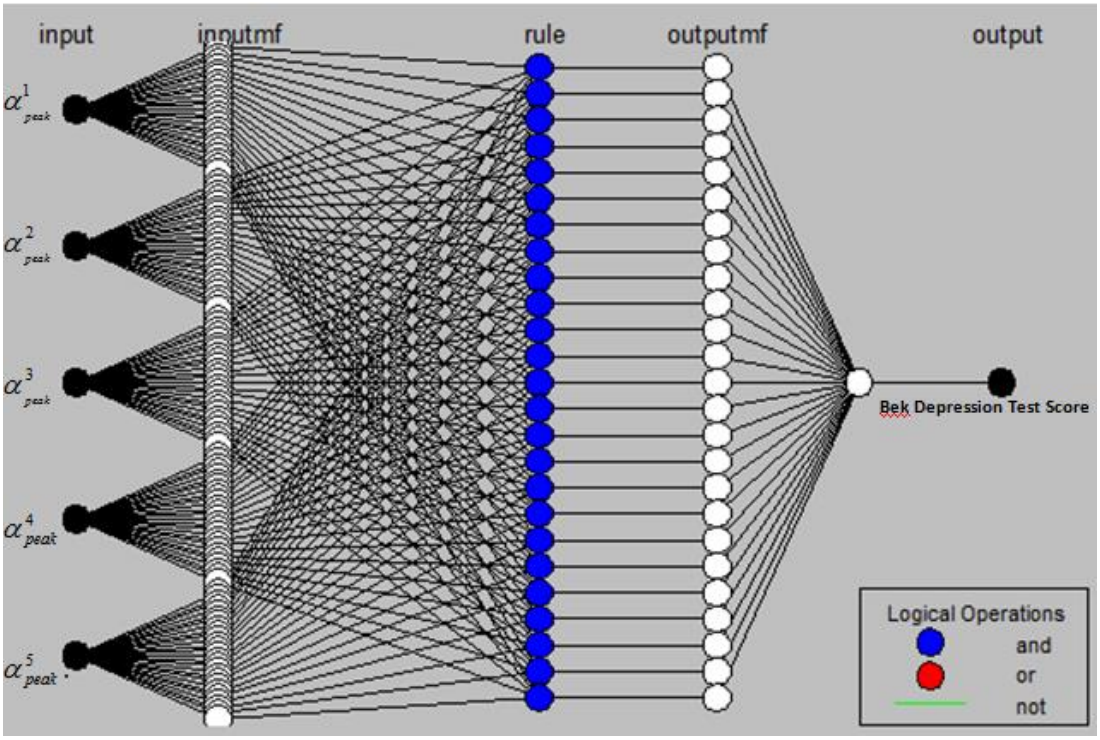

Figure 3: Noro-Fuzzy network with 5 inputs and a Beck output

The input of this model in this study involves five outputs of EEG from the point of F4 of depressed patients which is named $\alpha_{peakfrequancy}$. The point (F4) and $\alpha_{peakfrequancy}$ were selected to record regarding the previous studies.[11,12]In the mentioned which were conducted as the case studies on depressed people, the EEG of F4 of brain frontal was conducted on 107 right-hand depressed patients that was concurrent with displaying a moving film of different 5 emotional images from IAPS which classifies the emotional images based on their power of emotional stimulation. The data screen which has been collected by Procomp Infinity device in this research is demonstrated in Figure 4. On the right side is the displayed film which is observable on the monitor by the patient, and in the left side is the EEG and the Alpha peak diagram of his/her brain. After the end of the process, recording is started from Export Data (Figure 5) proportional to the time set extract of alpha pi; of EEG. In fact, in this phase the analogue is converted to the digital. Since there was the feedback of the brain to the five pictures in an extracted text file from EEG, another computerized program was written by the researcher (Raw EEG) that separated the raw EEG to pentamerous pieces corresponding to the images: the image 1= α^1_{peak}, image 2= α^2_{peak}, image 3= $\alpha^3_{peak,}$ image 4= $\alpha^4_{peak,}$ image 5= α^5_{peak}. These pieces were used as inputs in neural network and fuzzy-neural network.

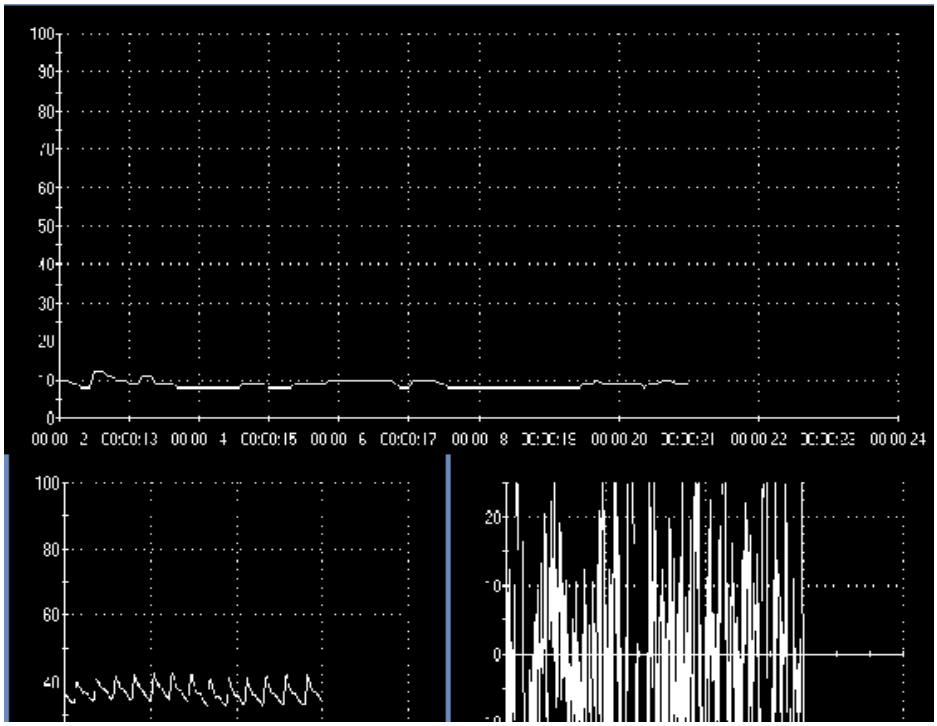

Figure 4: Procomp Infinity EEG recording window

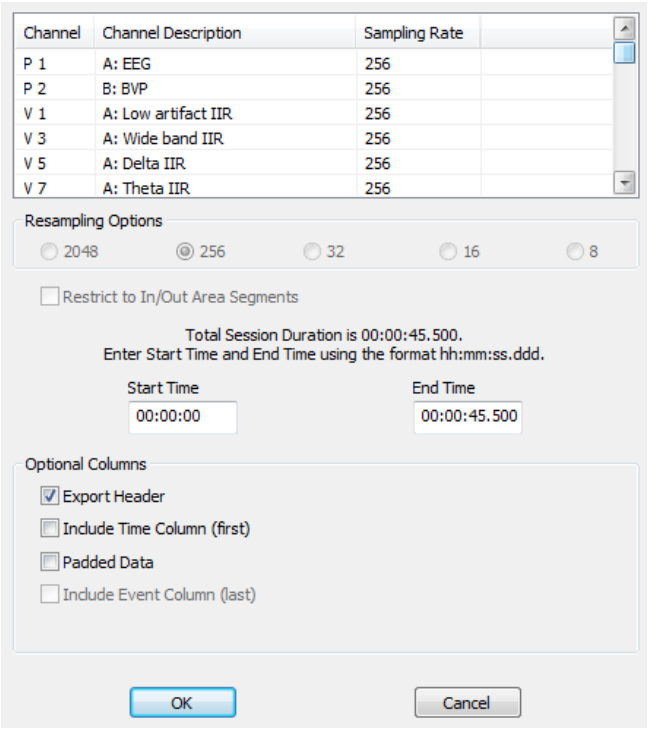

Figure 5: EEg data extract window in text format of Procomp Infinity

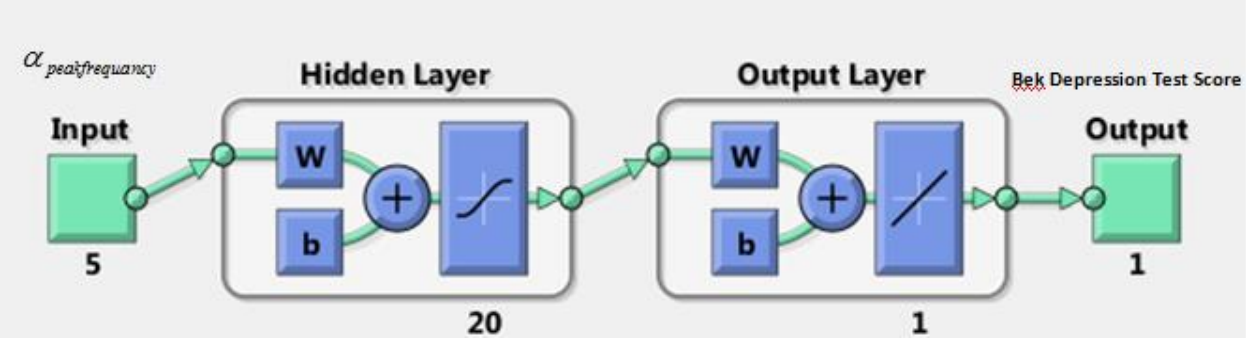

Figure 6: Architecture of the neural network with pureline output

RESULTS

To educate the membership function parameters in ANFIS, a compound of least square method and back-propagation gradient descent was used. The architecture of ANFIS is shown in Figure 1 and its experimental results are shown in Table2. The identification accuracy in this case is 87.2%. As demonstrated in Table3, the identification accuracy of a back-propagation algorithm is 66%.

Table 2: Experimental results for ANFIS

Node number	Learning time	Accuracy	Error
300	20%	87.2%	Near to zero

Table 3: Comparing the performances to obtain the best identification system

Network	Accuracy	Learning time/s	MSE
BPA Neural Network	66%	29%	6.83044 e-o
ANFIS Neuro-fuzzy	87.2%	20%	1.9978 e-06

Table 4 shows comparing the 2 networks in identification of increased positive mood in depressed people. Both networks were educated with similar data, but the learning time of ANFIS was lower and had more accuracy.

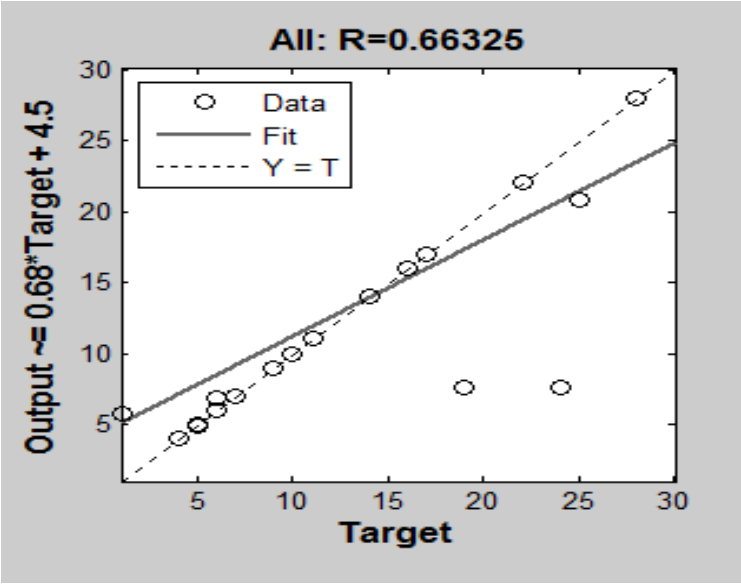

Figure 7: Comparing the 2 networks in identification of increased positive mood

Limitations of the study:Finding patients was a problem which is considered as a limitation in the study that took time and energy of the researcher.

Research strengths:Among the strengths of the present study, it can be said that if the research is successful, it will be promised that EEG of a point can be conducted cheaper than QEEG (Procomp) and only using a point to diagnose a disease without using paper-pencil tests.

Suggestions: 1. Using the 19- or 32-channel QEEG recording tools rather than Procomp; 2. Examining the results of the present study on the F3 point and comparing with the results of F4 (this study); 3. Using more samples.

DISCUSSION

Purpose of this study was to compare the diagnosis of depression in depressed patients by EEG, based on two algorithms: Artificial Nerve Networks and Neuro-Fuzy Networks. The findings of the research demonstrated that the depression scores of beck inventory can be predicted and explained with the accuracy of 87% using EEG in F4 and alpha peak frequency. In recent years some researchers have been attracted by this approach. Marks introduced a computerized system for phobic, panic, stress, obsession, and depression, which aimed to decrease the time spent by clinicians.[3] Razzouk reported a case study for modeling the diagnosis of schizophrenia and psychotic disorders.[4] Milla published a framework depended on fuzzy abnormal signs for modeling the inaccuracy and evaluation of depression. Begum extended a framework for diagnosis people stress using finger temperature.[5] Palanivel explained a neural method.[6] In that method, a radial basic function (RBF) and Back propagation were used which showed high accuracy in identifying the psychological problems, but study about its mechanism has explain a little about the method. Ariyanti reported a

fuzzy system in which he merged 21 testing question back 2.[7]

Chattopadhyay in an associated research called "Neurofuzzy models to automate the grading of old-age depression" has conducted different neurofuzzy networks for automatic rating between mild and moderate depressions which has developed a 94.4% forecast accuracy for this rating.[13]

Ekongin another study called "Intelligent Decision Support System for Depression Diagnosis Based on Neuro-fuzzy-CBR Hybrid" have attempted to develop an artificial neural network back propagation which distinguished a difference among three degrees of mild, moderate, and severe depression.[14] Hamilton's and Zunk's scales have been used at the entrance of these networks; the network distinguished the mild, moderate, and severe depressions with 100%, 77%, and 90% forecast accuracy, respectively.

In the above cases, the researchers have used different depression questionnaires for the artificial intelligence model entrance. The present study is the only one that its artificial intelligence model entrance is an extracted parameter from brain waves i.e,$\alpha_{peakfrequancy}$. In other studies, of course, such as the one conducted by Pradhan called "Detection of seizure activity in EEG by an artificial neural network: A preliminary study."[15] The entrance of this model was an epileptic patient, but the EEG has been used in the present study in order to analyze the depression.

The research can be the first step to predict and even identify depression using taking the data directly from the brain. So, there is no need for inventory and even a specialist diagnosis. Although there is a long way to reach that point, such researches demonstrate that can be moved in this direction and be closer to the target by accurate determination of brain point, accurate recording, and data process using efficient tolls and methods such as neuro-fuzzy networks. Furthermore, the research demonstrated that the artificial neuro-fuzzy network has a significant advantages compared with the artificial neural network.

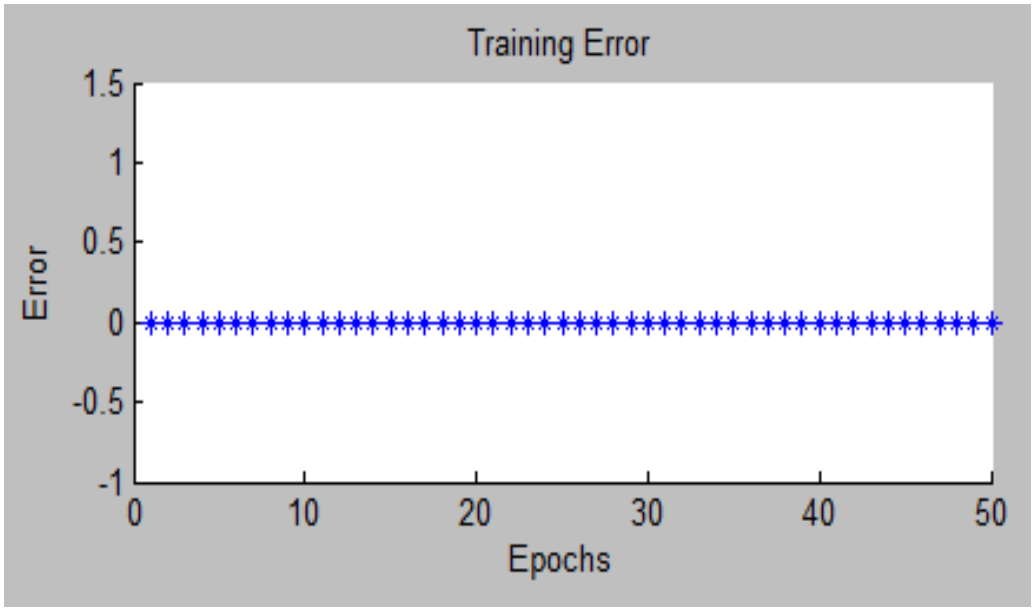

Figure 8: The little increasing of error in Matlab neuro-fuzzy network

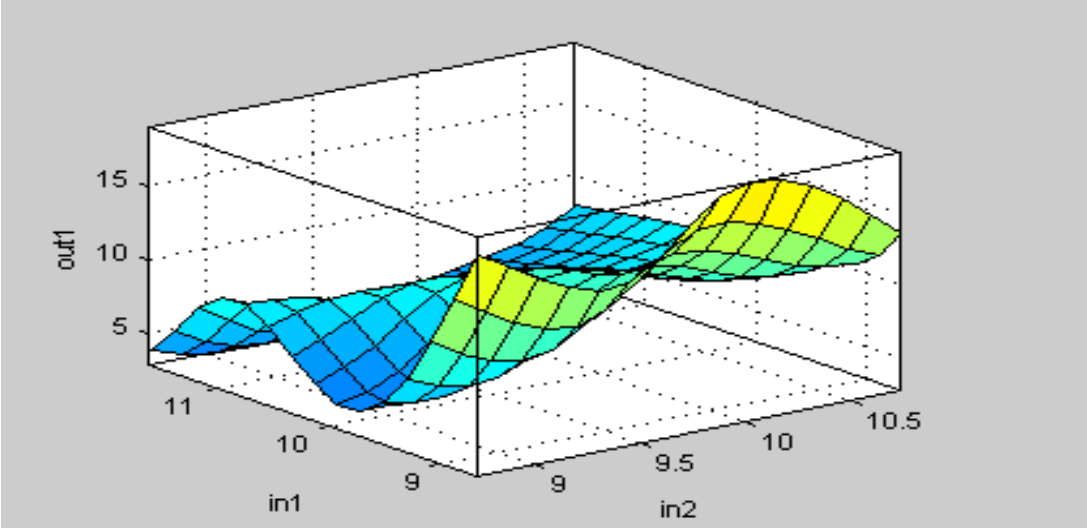

Figure 9: The increasing of Beck depression score in depressed people

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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