IJCSN International Journal of Computer Science and Network, Volume 5, Issue 1, February 2016
ISSN (Online) : 2277-5420 www.IJCSN.org
Impact Factor: 1.02

Implementation of Neuro Fuzzy System for Diagnosis of Multiple Sclerosis

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Abstract - Medical diagnosis is often done by expertise and experience of phisician, but sometimes may lead to misdiagnosis. Multiple sclerosis (MS) is a disease of the central nervous system. In this disease, body produces antibodies that attack and damage the Myelin, in which the myelin sheath (the insulation for nerve fibers) is in trouble and the damage to myelin in the central nervous system cause to disconnect between brain and other organs. The major problem is the lack of diagnosis. To improve diagnosis, Adaptive Neuro-Fuzzy Inference System (ANFIS) is used. ANFIS main idea is that using the way the nervous system of biological for data processing in order to learn and create the knowledge. This system uses neural network for learning, classification capabilities and modifying. There are several ways to train neural network. In this study, we use hybrid approach to train. This hybrid approach uses Back Propagation(BP) and Least Square Error(LSE). ANFIS has the ability to combine the linguistic power of fuzzy system with numeric power of neural network. For optimizing the input/output, the K-fold cross validation has been used. Implementation has been done in MATLAB. The Data set consist of 600 patients that each one has 6 columns, 5 of them is input and 1 of them is output that shows diagnosis.

Keywords - *Multiple Sclerosis, Fuzzy System, Neural Network, ANFIS, Hybrid Learning.*

1. Introduction

Artificial intelligence consist of research in computer science that it's targets is creating a computer that could reason such as human and help them make decision better. Decision support system is a computer software that design for diagnosis system. Multiple Sclerosis a kind of disease that starts with damage the myelin of brain and have some neurological symptoms like reducing the power of vision, spastic paralysis of limbs and impotency. Agboizebeta et al. colleague by providing a fuzzy cluster map analyze different kind of MS that help experts. They divided patients into ameliorative and primary progressive patient. Their model let to classify MS patient based on symptoms[26]. Borgohain and his colleague had implemented a fuzzy expert system for diagnosis of neural diseases, cerebral palsy of MS, muscular dystrophy and Parkinson disease. Their proposed system is a rule based expert system and run in JESS[1]. It use backward chain in inference engine. In it, user diagnosis disese by list of questionnaires and offers possible treatment[25]. Arabzadeh and his colleagues used a fuzzy rule based system in diagnosis MS. Decision making in their system is based on specification, signs and symptoms of people[35]. Adaptive neuro fuzzy inference system is a class of Adaptive network that in terms of performance is equivalent of fuzzy inference system. It use the method of neural network for process data and information for learning and creating knowledge.

It is a neuro fuzzy system that learn how set data using fuzzy rules and fuzzy sets. Seyit Ahmet and his colleagues proposed a technique to classify seven different forearm movements using SEMG[2] data which were received from 8 able bodied subjects. A 2-channel SEMG system was used for data acquisition and recording, then this raw electromyography (EMG) signals were applied to the wavelet denoising[47]. Mahmoodi and colleagues proposed a gene selection framework, based on wrapper model with neuro-fuzzy approach for cancer classification. ANFIS as a classifier for selected genes from PSO[3] or GA[4] methods applied on six datasets of microarray gene expression data for different cancers. ANFIS is compared

[1] Java expert system shell
[2] Surface Electromyography
[3] Particle Swarm Optimization
[4] Genetic algorithm

with three other classifiers which are SVM[1], KNN[2] and CART[3] [48]. Kumar and colleague proposed a system based on physio-psycho symptoms by using an ANFIS [46]. In this paper we use hybrid Learning for train ANFIS and optimize input data and validate ANFIS performance with k-fold cross validation.

2. Multiple Sclerosis

Multiple Sclerosis is an unpredictable clinical period that had been detected in white women more. It starts in 20 to 40 years old person but it may happen in any age. This chronic disease starts with damage the myelin of brain and spinal cord that lead to nervous symptoms. It starts when white blood cell attack and damage the myelin. Myelin is a sheath for nerve fibers and help to transfer message faster. Each time white blood cells attack nerve fibers relate to some organs, they make problem for that organs [37]. Phisicians are suspicious to MS when they face the patient with movement and sensorial symptoms. Some of neurological symptoms that seen in MS is seeing blurry sensorial symptoms, lack of balance, spoken failure, oaresis and sensory disorders. Phisicians diagnose it according to clinical result and diagnostic criteria that could be seen in Magnetic Resonance Imaging [6].

3. Magnetic Resonance Imaging

MRI has important role in assessment the waste of brain and other tissues in evaluate the disease and related pathophysiology perception. The best way to show the part of nervous system where myelin is destroyed there is MS plaques that could be seen in MRI [6]. The recognition of MS is based on existence of plaques in centeral nervous system plaques are seen around cerebal ventricles. MRI of brain and spinal cord are the most sensitive method of MS recognition such as show the damaged area.

MRI show the waste related to injured myelin in brain with defined limit. It shows the lesions and indicate the injured part of tissue to help the phisicians in recognition of MS. White matter lesion is a kind of structural changes in brain. It's important feature is the destructed myelin of brain. MRI indicates this area in white color [11].

[1] Support Vector Machine
[2] K-Nearest Neighbor
[3] Classification And Regression Trees

4. Adaptive Neuro Fuzzy Inference System

ANFIS is a class of adaptive networks that in terms of performance is equivalent to fuzzy inference system. It is the combination of neural network with Fuzzy inference system. It offers a powerful template to resolve the categories problem. It learn in short time and could make decision in different situation [52]. A key element of this idea is create the new structure to process the information. This system composed of many numbers of highly interconnected processing elements that called neuron. ANFIS is a neural network that learn how to set the data with fuzzy rules and fuzzy sets. In it we could find out which rule has developed with system and why a particular answer give to input selection. Experts could check this rules to find the problem [13]. It could be a system with fuzzy rules if the existence knowledge state in form of linguistic rule and if the data is available or system could learn from simulation and examples, it could be use of neural network. ANFIS use neural network and fuzzy rules between input and output. It include 5 layers:

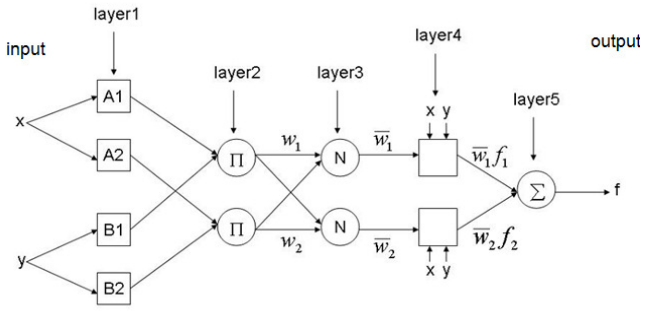

Fig.1 Architectural layers of ANFIS

1. Input layer: First layer of ANFIS include some nodes as adaptive nodes. In this layer fuzzy membership degree determined in accordance with inputs. It's output is input membership degree that is shown in eq1 and eq2.

$$O_{1,i} = \mu_{A_i}(x) \qquad for\ i = 1,2 \tag{1}$$

$$O_{1,i} = \mu_{B_{i-2}}(y) \qquad for\ i = 3,4 \tag{2}$$

2. Fuzzy input membership function: Each node in this layer is fixed. Neurons in it show the fuzzy membership function for existence input in system. It's output is shown in eq3 actually is equivalent of if part.

$$O_{2,i} = w_i = \mu_{A_i}(x)\mu_{B_i}(y) \tag{3}$$

3. Fuzzy rules: The nodes are fix in this layer and doing the role of normalization of fire rate of pervious layer. It's output obtained in eq4:

$$O_{3,i} = \overline{w}_i = \frac{w_i}{w_1 + w_2} \qquad i = 1,2 \tag{4}$$

4. Fuzzy output membership function: In this layer, the nodes are adaptive. Output calculate in eq5:

$$O_{4,i} = \overline{w}_i f_i = \overline{w}_i \left(p_i x + q_i y + r_i \right) \tag{5}$$

p_i, q_i, r_i are output parameters.

5. Output layer: indicate a fix node which is the sum of input signals on it:

$$O_{5,i} = \sum_i \overline{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \tag{6}$$

5. K-fold Cross Validation

This is a high accuracy technique for learning a neural network. It had some benefit such as don't need independent dataset. If a network is built using a specific learning dataset, it is necessary to have test data samples independent of the learning dataset that was used to train the network. However, it is difficult or expensive to obtain independent test data frequently and moreover it is undesirable to hold back data from the learning dataset to use for a separate test because that weakens the learning dataset.

K-fold cross validation is a technique for performing independent tests without requiring separate test datasets and without reducing the data used to build the network. The general idea of this method is to divide the overall sample into a number of folds, say k. The same type of analysis is then successively applied to the observations belonging to all the K-1 folds (training samples), and the results of the analysis are applied to the testing sample, which is the K^{th} sample (the sample or fold that was not used). This is repeated until K random samples are drawn from the data for the analysis. The results for the K replications are aggregated (averaged) to yield a single measure of the stability of the respective model, i.e. the validity of the model for predicting new observations. Thus, this technique allows the analyst to evaluate the overall accuracy of the respective prediction model or method in repeatedly drawn random samples.

6. Proposed Method

6.1 Input Data

For access data we use article [15]. We use features white matter forms as follow: volume, sphericity, compactness, tissue contrast, environment. Our dataset consist of 600 patients that has 6 columns. 5 of them are white matter feature and 1 of them is result that characterized by 1 (indicate the person has MS) or 2(the person does not have MS). Each row corresponds to a person's features.

6.2 ANFIS Model for Diagnosis MS

ANFIS is a hybrid model that contain s a combination of neural network and fuzzy systems. First, fuzzy inference system that include primary fuzzy model and is formed. It is base on fuzzy rules that extracted from input output data. At next step, neural network is used to improve primary fuzzy rule. In anfis model the network is trained with different technique. Here we use a hybrid algorithm for training. During the training process dataset is shown cyclic to ANFIS. Each cycle among all the training samples is called epoch. Each epoch of ANFIS learning algorithm contain a forward path and backward path. The purpose of forward path is forming and adjust the result parameters. We use Least Square Estimation(LSE) in forward path.

$$MSE = \frac{\sum_1^n \left(z_0 - z_p \right)^2}{n} \tag{7}$$

The backward path adjust the parameters of activation functions. Back Propagation(BP) had been used in backward path.

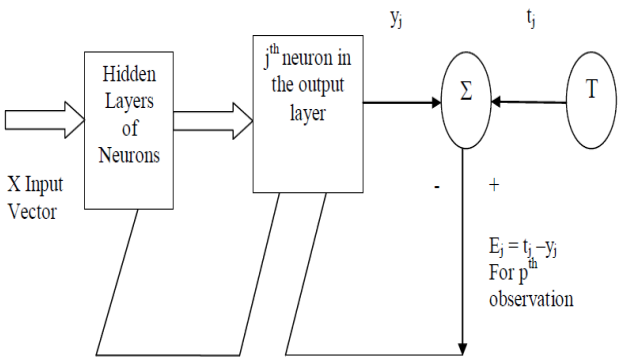

Fig.2 Learning error correction in neural network

The total error for P^{th} dataset and J^{th} neuron in output layer are calculate as follow:

$$E_i = t_i - y_i \quad (8)$$

By using K-fold techniques we divided data set into 10 fold. 1 of them are used for test and 9 of them are used for training system. We set 5 epoch for training and after this 5 epoch with 9 fold of training, test fold are used to evaluate the system performance. Next step we used another fold for test and have 9 fold for training with 5 epoch. This step is repeated until all the fold be used for test. That's why we used 5 epoch to reduce the error rate. In each epoch LSE adjust result parameters and the value of Mean Square Error is counted and in PB the error rate propagate to input to update the parameters to produce best result.

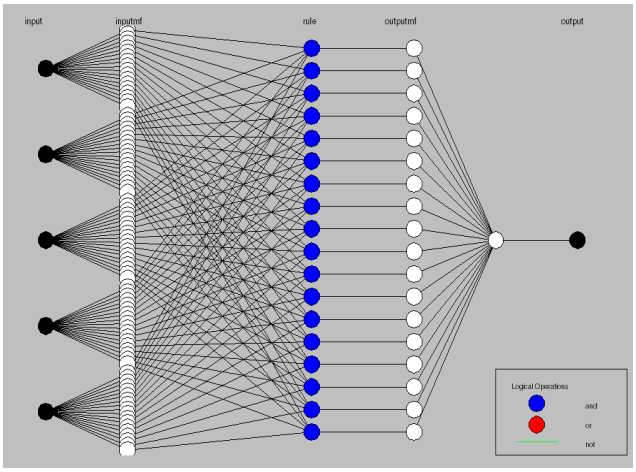

Fig.3 The rule structure in ANFIS with hybrid learning

The features are measured according to fuzzy rules. Fuzzy inference system produce 18 rules due to the inputs. We optimize this rules and obtained 7 rules. This rules that used for specify target in linguistic variables as follow:

1. If Sphericity is low, compactness is high, volume is low, tissue contrast is high and surrounding is high and medium then tissue structure is abnormal.
2. If Sphericity is low, compactness is high, volume is low, tissue contrast is modest and surrounding is high then tissue structure is abnormal.
3. If Sphericity is low, compactness is high, volume is high, tissue contrast is high and surrounding is high and modest then tissue structure is abnormal.
4. If Sphericity is low, compactness is high, volume is high, tissue contrast is modest and surrounding is high then tissue structure is abnormal.
5. If Sphericity is high, compactness is low, volume is high, tissue contrast is large-scale and surrounding is low then tissue structure is abnormal.
6. If Sphericity is low, compactness is low, volume is low, tissue contrast is high and surrounding is high then tissue structure is abnormal.
7. In other cases, tissue structure is normal.

7. Simulation Results

We implement the proposed ANFIS and compare it with ANFIS with BP learning algorithm and General Regression Neural Network(GRNN). Confusion matrix is used for evaluate result:

TP: How many MS patients are correctly diagnosed.

FP: How many MS patients have been diagnosis wrong as healthy.

TN: How many healthy person are correctly diagnosed healthy.

FN: How many healthy people were diagnosed MS patient wrong.

P: How many people are classified correct.

N: How many people are classified incorrectly.

Sensitivity: How much this test could select MS patient correctly.

Specificity: It means the ability of test to select the healthy person.

Accuracy: availability of system in diagnosis and classify the cases.

We use the method in same situation and use K- fold cross validation in all of them and the result are:

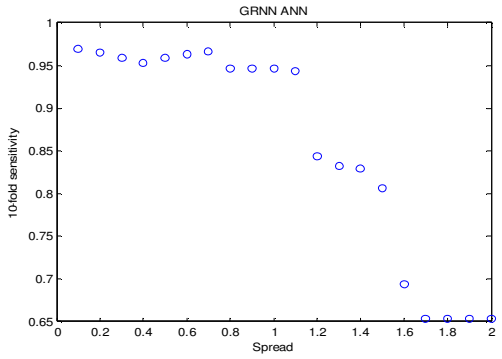

Fig.4 sesitivity in GRNN

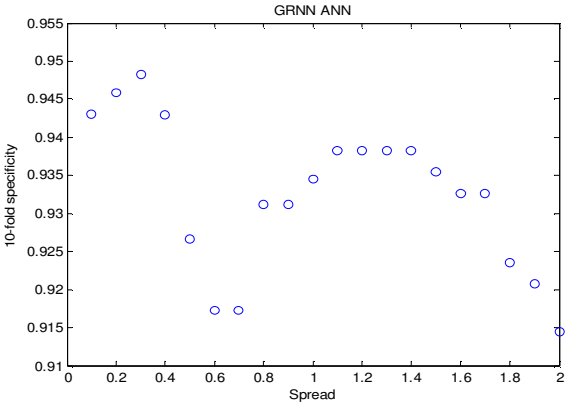

Fig.5 Specificity in GRNN

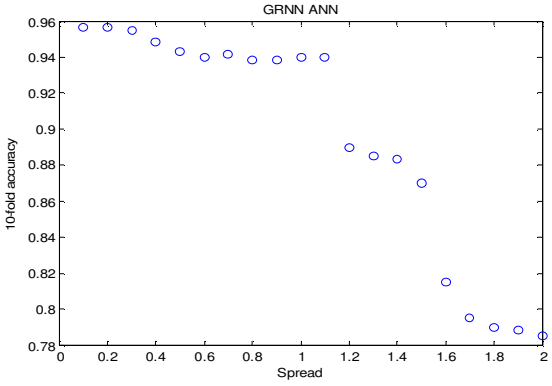

Fig .6 Accuraacy in GRNN

$$TPR = TP/P = TP/(TP + FN) = 28.5/(28.5 + 0.9) = 0.9693$$

$$SPC = TN/N = TN/(FP + TN) = 28.9/(1.7 + 28.9) = 0.944$$

$$ACC = (TP+TN)/(P+N) = (28.5+28.9)/(28.5+0.9+1.7+28.9) = 0.9566$$

In ANFIS with BP learning algorithm the result as follow:

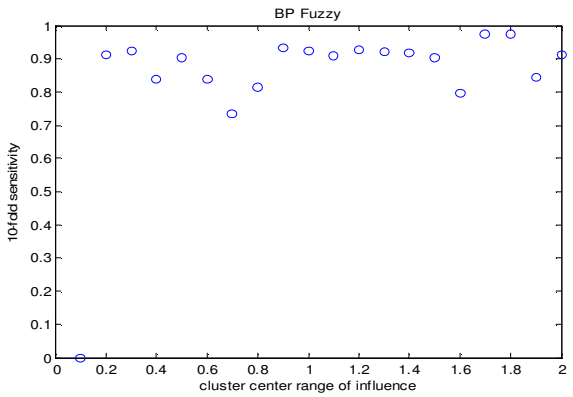

Fig.7 Sensitivity in ANFIS with BP

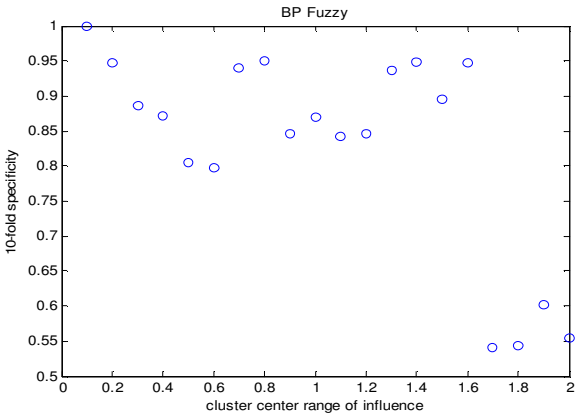

Fig.8 Specificity in ANFIS with BP

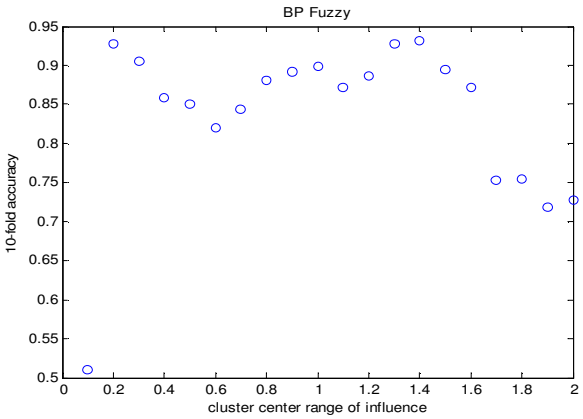

Fig.9 Accuracy in ANFIS with BP

$$TPR = TP/P = TP/(TP + FN) = 26.7/(26.7 + 2.7) = 0.9081$$

$$SPC = TN/N = TN/(FP + TN) = 29/(29 + 1.6) = 0.9477$$

$$ACC = (TP+TN)/(P+N) = (26.7+29)/(26.7+2.7+1.6+29) = 0.9283$$

In proposed ANFIS that use the hybrid learning algorithm the result are as follow:

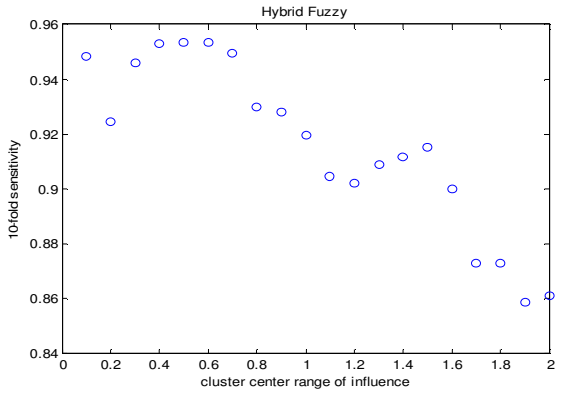

Fig.10 Sesitivity inANFIS with hybrid learning

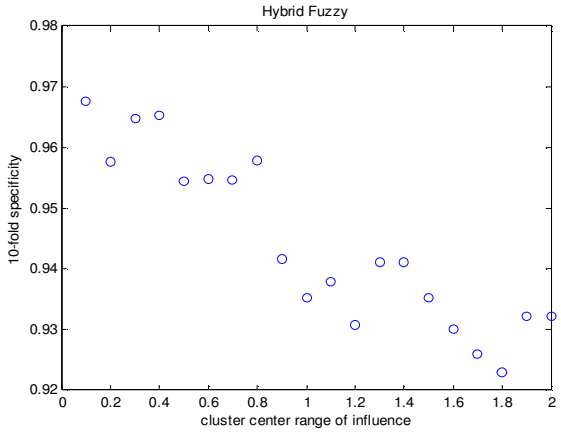

Fig.11 Specificity in ANFIS with hybrid learning

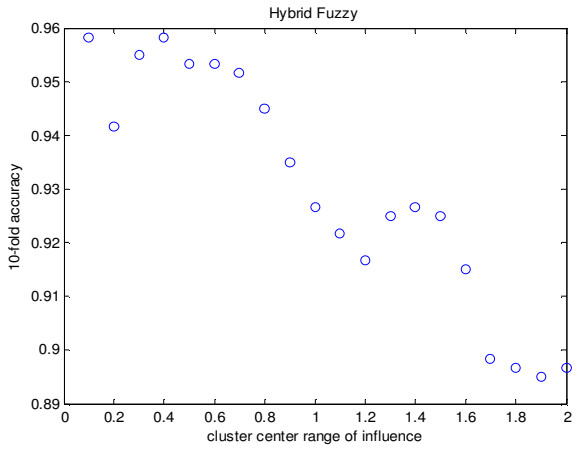

Fig.12 Accuracy in Anfis with hybrid learning

$$TPR = TP/P = TP/(TP + FN) = 27.9/(27.9 + 1.5) = 0.9489$$

$$SPC = TN/N = TN/(FP + TN) = 29.6/(29.6 + 1) = 0.9673$$

$$ACC = (TP+TN)/(P+N) = (27.9+29.6)/(27.9+1.5+1+29.6) = 0.9583$$

8. Conclusions

Decision support system play an important role in patient care. False detection in each kind of diseases have an irreparable damage to patients and clinican. The aim of this study is improve diagnosis of MS. We had tried to bring the learning ability of neural network into fuzzy inference system to improve the diagnosis of MS. We use 600 patient's data consist of 5 features and use hybrid learning algorithm in ANFIS that applied Least Square Estimation (LSE) and Back Propagation (BP) to reduce the diagnosis error. For optimize the input data and evaluate the performance of our system we use K-fold cross validation. Proposed system compared with ANFIS with BP algorithm and GRNN. Simulation result show that proposed system has almost 96% accuracy.

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