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Research Article

Exploring ANFIS Model for Osteoarthritis Disease Classification

Suvarna M. Patil[Ȧ*] and Ravindra R.Mudholkar[Ḃ]

[Ȧ]Department of Computer Studies, BVDU, Institute of Management, Sangli, India
[Ḃ]Department of Electronics, Shivaji University,Kolhapur, India

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Abstract

Fuzzy Inference systems have given rise to wide applicability in the medical domain. Adaptive Neural Fuzzy Inference System (ANFIS) is blender of neural network and fuzzy logic, which extracts and combines the best of both. ANFIS uses a black box approach, which is a peculiar characteristic. This paper discusses about three methods used for the diagnosis of Osteoarthritis disease namely- Mamdani method, Sugeno method and ANFIS method. It further presents a comparative performance of these methods.

Keywords: *ANFIS Model, Osteoarthritis disease etc.*

1. Introduction

Health is the most precious asset of our life. Since body is a very complicated natural machine even slightest disturbance to health causes immense discomfiture to us. There is variety of diseases that needs treatment. One such related to bones is called as *Osteoarthritis*. Treatment of this disease at its initial stages will prevent a patient from getting crippled for life. There are 10 systems in the human body (*http://wiki.answers.com*). It includes Circulatory System, Dermal, Digestive System, Endocrine System, Excretory System, Muscular System, Nervous System, Reproductive System, Respiratory System, and Skeletal System. The skeletal system includes all of the bones, joints, ligaments, and tendons of the body.

One of the major complaints related to arthritis is essentially concerned to the bones. There are varieties of arthritic diseases. When treated at its infancy, the disease can be completely cured or at least kept within limits without doing much damage to health of the patient. Experience and skill of Expert Doctors is the backbone of successful diagnoses. The diagnostic process is dependent on the subjective abilities of these healthcare professionals that carry risk of failure. The rate of failure in diagnosis is high in case of novice doctors, because the skill of diagnose the symptoms like pain, comfort, discomfort, fear, shivering, etc. is primarily based on subjective evaluation. Thus, the field of medical science needs a support of technology such as Soft Computing, for better assessment of information objectively. This paper focuses on a degenerative joint disease i.e. Osteoarthritis as a problem domain.

The work has been done for use of hybrid Genetic Algorithm and Artificial Neural Network Fuzzy Inference System (ANFIS) for Brain Tumor Segmentation, using medical image processing. After providing the image, the features are extracted from the image with the help of hybrid genetic algorithm (Minakshi Sharma *et al*, 2012). The final accuracy of the proposed work is stated to be 97%. The conventional method in medicine for brain MR images classification and tumor detection is performed by human inspection. Some researchers have published their work regarding medical image classification using ANFIS technique for brain tumor (Anant Bhardwaj *et al*, 2013). The performance of the ANFIS classifier was evaluated in terms of training performance and classification accuracy. The proposed ANFIS classifier resulted with accuracy greater than 90% has potential in detecting the tumors. In one study PLANN (Partial Logistic Artificial Neural Network) and ANFIS is applied to Nottingham cancer data set for obtaining probability of conditional failure and to get the curve of survival of the patient(Hazlina Hamdan *et al*, 2010)). They have performed data pre-processing before it is being used by model.

The paper is organized as follows: the architecture and underlying working of ANFIS is described in section II with short description about the other methods used. Section III explains the design of the model where Mamdani, Sugeno, ANFIS method is used for diagnosis the osteoarthritis disease. The section IV focuses on the results obtained from the model and the comparison, discussion on the result is covered in Section V. Section VI highlights the conclusions.

2. Classification Methods

a) Mamdani's Method: Mamdani's Fuzzy Inference Method is the first rule based model and most commonly seen fuzzy methodology developed by E.H.Mamdani. It was proposed in the 1980s and was among the first control systems built using Fuzzy Set Theory(Yen and Langari, 2006). Mamdani model combines inference results of rules

*Corresponding author: **Suvarna M. Patil**

Table 1: Layers in ANFIS (Sivanandanam *et al*, 2010)

Layer Number	Description	Formula
Layer 1	Compute the matching degree to a fuzzy condition involving one variable.	$O_{1,i} = \mu_{A_i}(x) \quad for\, i = 1,2$
Layer 2	Every node in this layer is fixed. This is where the t-norm is used to 'AND' the membership grades.	$O_{2,i} = w_i = \mu_{A_i}(x)\mu_{B_i}(y), \quad i = 1,2$
Layer 3	It calculates the ratio of the firing strengths of the rules.	$O_{3,i} = \overline{w}_i = \frac{w_i}{w_1 + w_2}$
Layer 4	Compute the conclusion inferred by fuzzy rule.	$O_{4,i} = \overline{w}_i f_i = \overline{w}_i (p_i x + q_i y + r_i)$
Layer 5	There is a single node here that computes the overall output.	$O_{5,i} = \sum_i \overline{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}$

using superimposition and not the addition. Hence it is a non-additive rule model.

The Mamdani model use rules whose consequent part is Fuzzy Set:

Ri :*If* x_1 is A_{i1} and x_2 is A_{i2} and … and x_s is A_{is}*Then* y is C_i, i=1,2,…,M (1)

Where 'M' is the number of fuzzy rules, xj∈Uj (j=1,2,…s) are the input variables, y∈Y is the output variable, and Aij and Ci are fuzzy sets characterized by membership functions $\mu A_{ij}(x_j)$ and $\mu C_i(y)$ respectively. The advantages of Mamdani model include wide acceptance and suitability for human input.

b) Sugeno's Method: The model was first introduced by T.Takagi and M.Sugeno around 1985. Another student of Sugeno, K.T.Kang, continued his work. It is an additive rule model. The main advantage of TSK model is that it can approximate a function using fewer rules.

The TSK model uses a rule whose 'then' part is a linear model:

Ri: *If* x_1 is A_{i1} and x_2 is A_{i2} and … x_s is A_{is}*Then* $y=f_i(x_1,x_2,\ldots x_s)$, i=1,2,…,M(2)

Where'fi' is a linear function.

The motivation for developing this model was to reduce the number of rules required by Mamdani model. This was achieved by replacing the consequent of rule with a linear equation of input variables. TSK method gives an advantage of greater computational efficiency.

c) ANFIS Method: ANFIS is an adaptive network. An adaptive network is composed of nodes and directional links. Associated with the network is a learning rule - for example back propagation. It is called adaptive because some, or all, of the nodes have parameters which affect the output of the node. These networks are capable of learning a relationship between inputs and outputs. The structure of the network is shown in Fig. 1

The description and calculation of each layer is shown in Table 1. The Layer 0 is responsible to accept the input, therefore it is not considered in the Table 1. The input vector is fed through the network layer by layer.

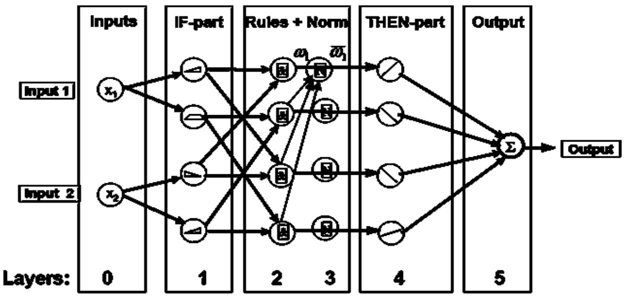

Fig.1 ANFIS Network **(**Sivanandanam *et al*, 2010**)**

This Neuro Adaptive Learning Technique provides a method for the fuzzy modeling procedure to learn information about a data set, in order to compute the membership function parameters that best allow the associated fuzzy inference system to track the given input/output data. This learning method works similarly to that of Neural Networks. The work done in (Hosseini *et al*,2012; Jang *et al*,1993; Ghatage *et al*, 2012; Gaadi *et al*, 2011; Esmaeili *et al*, 2012; Boyacioglu *et al*,2010) is purely based on ANFIS technique.

3. ANFIS Model for Diagnosis of Disease

The database of patients is collected from Bharati Medical Hospital, Sangli, who were suffering from Osteoarthritis (OA) disease. The diagnosis for Knee Osteoarthritis is based on the five symptoms as follows

- *Age*
- *Morning Stiffness*
- *Crepitus*
- *Bony Tenderness*
- *Warmth to Touch*

The collected data is highly nonlinear and it is likely that the traditional method of classification may fail in such cases. The three models are designed for the diagnosis of Knee Osteoarthritis using Mamdani, Sugeno and ANFIS techniques. The three layered architecture of the system is shown in Fig 2. The Layer-1 is the user of the system, who may be an Assistant to Doctor or General Medical Practitioner.

Table

Input Variable

Variable			
Age	$\mu_{Young}(x) = \begin{cases} (x-46)/45, & -46 \le x < 1 \\ 1, & x = 1 \\ (40-x)/39, & 1 \le x < 40 \end{cases}$	$\mu_{Adult}(x) = \begin{cases} (x-30)/30, & 30 \le x < 60 \\ 1, & x = 60 \\ (90-x)/30, & 60 \le x < 90 \end{cases}$	$\mu_{Old}(x) = \begin{cases} (x-65)/55, & 65 \le x < 120 \\ 1, & x = 120 \\ (160-x)/40, & 120 \le x < 160 \end{cases}$
Morning Stiffness	$\mu_{Less}(x) = \begin{cases} (x-24)/24, & -24 \le x < 0 \\ 1, & x = 0 \\ (25-x)/25, & 0 \le x < 25 \end{cases}$	$\mu_{Average}(x) = \begin{cases} (x-15)/20, & 15 \le x < 35 \\ 1, & x = 35 \\ (60-x)/30, & 35 \le x < 60 \end{cases}$	$\mu_{AboveAverage}(x) = \begin{cases} (x-40)/20, & 40 \le x < 60 \\ 1, & x = 60 \\ (90-x)/30, & 60 \le x < 90 \end{cases}$
Crepitus	$\mu_{Low}(x) = \begin{cases} (x-2.6)/1.6, & -2.6 \le x < 1 \\ 1, & x = 1 \\ (5-x)/4, & 1 \le x < 5 \end{cases}$	$\mu_{Medium}(x) = \begin{cases} (x-2)/4, & 2 \le x < 6 \\ 1, & x = 6 \\ (9-x)/3, & 6 \le x < 9 \end{cases}$	$\mu_{High}(x) = \begin{cases} (x-6.5)/3.5, & 6.5 \le x < 10 \\ 1, & x = 10 \\ (15-x)/5, & 10 \le x < 15 \end{cases}$
Bony Tenderness	$\mu_{Little}(x) = \begin{cases} (x-2.5)/1.5, & -2.5 \le x < 1 \\ 1, & x = 1 \\ (3.5-x)/2.5, & 1 \le x < 3.5 \end{cases}$	$\mu_{Medium}(x) = \begin{cases} (x-2)/4, & 2 \le x < 6 \\ 1, & x = 6 \\ (10-x)/4, & 6 \le x < 10 \end{cases}$	$\mu_{High}(x) = \begin{cases} (x-6/4, & 6 \le x < 10 \\ 1, & x = 10 \\ (15-x)/5, & 10 \le x < 15 \end{cases}$
Warmth to touch of joint	$\mu_{No}(x) = \begin{cases} (x-0.3)/0.3, & -0.3 \le x < 0 \\ 1, & x = 0 \\ (1-x)/1, & 0 \le x < 1 \end{cases}$	$\mu_{Yes}(x) = \begin{cases} (x-0)/1, & 0 \le x < 1 \\ 1, & x = 1 \\ (5-x)/4, & 1 \le x < 5 \end{cases}$	

Output Variable

Variable			
Knee OA Severity	$\mu_{No}(x) = \begin{cases} (x-2.6)/1.6, & -2.6 \le x < 1 \\ 1, & x = 1 \\ (1-x)/0, & 1 \le x < 1 \end{cases}$	$\mu_{StageI}(x) = \begin{cases} (x-0.6)/3.4, & 0.6 \le x < 4 \\ 1, & x = 4 \\ (8-x)/4, & 4 \le x < 8 \end{cases}$	$\mu_{StageII}(x) = \begin{cases} (x-3)/4, & 3 \le x < 7 \\ 1, & x = 7 \\ (10-x)/3, & 7 \le x < 10 \end{cases}$
	$\mu_{Gross}(x) = \begin{cases} (x-5)/5, & 5 \le x < 10 \\ 1, & x = 10 \\ (14-x)/4, & 10 \le x < 14 \end{cases}$		

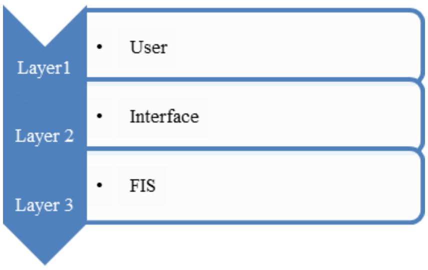

Fig.2 Architecture of the Diagnostic system

In the layer-2, user will accept inputs in terms of symptoms from the patient with the help of interface. These inputs/symptoms appear on the case paper of the patient. In the layer-3 FIS resides, which does the actual task of decision making involved in the process of diagnosis. The design of Knee OA FIS using Mamdani method is shown in the Fig. 3

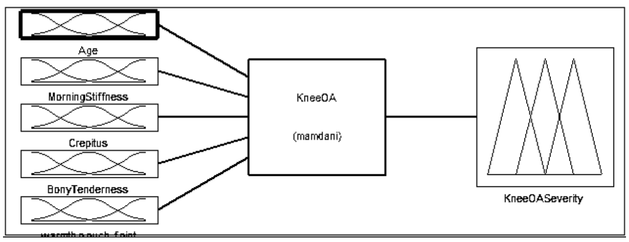

Fig. 3 Design of Knee OA FIS (Mamdani Method)

Summary of the variables used in Knee OA FIS is given in the Table 3.

Table 3: Summary of Knee OA FIS

Sr.No.	Variable Type	Name of Variable	Range of Variable	Number of Membership Functions
1	Input	Age	1 to 120	3
2	Input	Morning Stiffness	0 to 60	3
3	Input	Crepitus	1 to 10	3
4	Input	Bony Tenderness	1 to 10	3
5	Input	Warmth_to_touch_of_Joint	0 or 1	2
6	Output	KneeOASeverity	1 to 10	4

Table 4: Details of Output Variables for Knee OA (Sugeno method)

Sr. No	Name of Membership Function	Constant value Assigned
1	NoOA	0
2	StageI	3
3	StageII	7
4	Gross	9

Table 5: Results of Knee OA FIS using Mamdani approach

Case No.	Doctor Diagnosis (Estimated Output)	Mamdani Diagnosis (Observed Output)	Error (ξ)	Case No.	Doctor Diagnosis (Estimated Output)	Mamdani Diagnosis (Observed Output)	Error (ξ)
1	5	4.8809	0.2191	31	5	5.0000	0.0000
2	3	4.2546	1.2546	32	6	5.0000	1.0000
3	3	4.2667	1.2667	33	2	4.2624	2.2624
4	3	4.3102	1.3102	34	2	5.0000	3.0000
5	3	5.0000	2.0000	35	3	5.0000	2.0000
6	2	4.2799	2.2799	36	8	7.9465	0.0535
7	0	3.6376	3.6376	37	0	0.5000	0.5000
8	3	5.0000	2.0000	38	2	4.2890	2.2890
9	8	7.6599	0.3401	39	2	4.2799	2.2799
10	8	5.0000	3.0000	40	2	4.2667	2.2667
11	3	4.2799	1.2799	41	3	5.0000	2.0000
12	7	7.6814	0.6814	42	0	0.5000	0.5000
13	0	0.5000	0.5000	43	5	5.0000	0.0000
14	4	5.0000	1.0000	44	0	0.5271	0.5271
15	2	4.2399	2.2399	45	0	0.5000	0.5000
16	6	5.0000	1.0000	46	0	0.5000	0.5000
17	2	4.3102	2.3102	47	7	5.4427	1.5573
18	3	4.2667	1.2667	48	0	0.5000	0.5000
19	3	4.3102	1.3102	49	0	0.5000	0.5000
20	4	5.0000	1.0000	50	8	7.7659	0.2341
21	6	5.0000	1.0000	51	0	0.5000	0.5000
22	1	4.2992	3.2992	52	0	0.5227	0.5227
23	0	0.5000	0.5000	53	0	0.5000	0.5000
24	5	5.0000	0.0000	54	5	5.0000	0.0000
25	8	7.9465	0.0535	55	0	0.5000	0.5000
26	8	5.0000	3.0000	56	0	0.5000	0.5000
27	6	5.0000	1.0000	57	4	4.2546	0.2546
28	7	7.5723	0.5723	58	0	0.5000	0.5000
29	8	7.5944	0.4056	59	6	5.0000	1.0000
30	3	5.0000	2.0000	60	0	0.5000	0.5000

Table 6: Results of Knee OA FIS using Sugeno method

Case No.	Doctor Diagnosis (Estimated Output)	Sugeno Diagnosis (Observed Output)	Error (ξ)	Case No.	Doctor Diagnosis (Estimated Output)	Sugeno Diagnosis (Observed Output)	Error (ξ)
1	5	4.8571	0.1429	31	5	0.5000	4.5000
2	3	4.0000	1.0000	32	6	1.3455	4.6545
3	3	4.0000	1.0000	33	2	4.0000	2.0000
4	3	0.5000	2.5000	34	2	0.5000	1.5000
5	3	0.5000	2.5000	35	3	0.5000	2.5000
6	2	1.3793	0.6207	36	8	9.0000	1.0000
7	0	0.9981	0.9981	37	0	0.0000	0.0000
8	3	0.5000	2.5000	38	2	1.3793	0.6207
9	8	9.0000	1.0000	39	2	1.8964	0.1036
10	8	7.0000	1.0000	40	2	4.0000	2.0000
11	3	2.2529	0.7471	41	3	0.5000	2.5000
12	7	9.0000	2.0000	42	0	0.0000	0.0000
13	0	0.0000	0.0000	43	5	0.5000	4.5000
14	4	0.5000	3.5000	44	0	0.0000	0.0000
15	2	4.0000	2.0000	45	0	0.0000	0.0000
16	6	1.3201	4.6799	46	0	0.0000	0.0000
17	2	0.5000	1.5000	47	7	9.0000	2.0000
18	3	4.0000	1.0000	48	0	0.0000	0.0000
19	3	0.5000	2.5000	49	0	0.0000	0.0000
20	4	0.5000	3.5000	50	8	9.0000	1.0000
21	6	1.2442	4.7558	51	0	0.0000	0.0000
22	1	4.0000	3.0000	52	0	0.0000	0.0000
23	0	0.0000	0.0000	53	0	0.0000	0.0000
24	5	0.5000	4.5000	54	5	0.5000	4.5000
25	8	9.0000	1.0000	55	0	0.0000	0.0000
26	8	7.0000	1.0000	56	0	0.0000	0.0000
27	6	1.2320	4.7680	57	4	4.0000	0.0000
28	7	9.0000	2.0000	58	0	0.0000	0.0000
29	8	9.0000	1.0000	59	6	1.2000	4.8000
30	3	0.5000	2.5000	60	0	0.0000	0.0000

The ranges of membership function used for each Input and Output variables are shown in table 2

Considering the same input variables, the model for Knee OA diagnosis is prepared using Sugeno approach. Fig. 4 shows the structure of FIS.

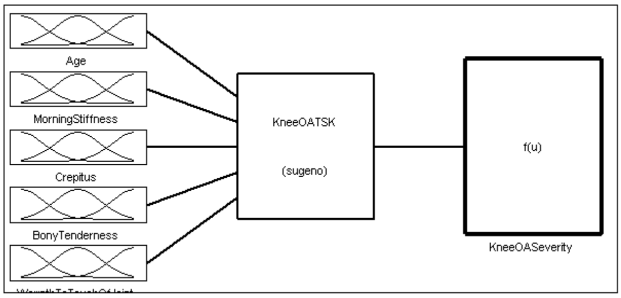

Fig. 4 Design of Knee OA FIS (Sugeno method)

In case of Sugeno method consequent part is in the form of linear function. It requires constants to be assigned to each membership function. Table 4 specifies the constant values assigned to each output membership function.

And finally the FIS is created with triangular membership functions in combination with linear function for output variable in ANFIS. The structure of ANFIS for Knee OA diagnosis is given as software listing 1.

Software Listing: 1

```
Number of nodes: 524
Number of linear parameters: 1458
Number of nonlinear parameters: 46
Total number of parameters: 1504
Number of training data pairs: 60
Number of checking data pairs: 0
Number of fuzzy rules: 243
```

4. Results

Mamdani method used for Knee OA Diagnosis the involved a rule base comprising 43 rules. The model is tested with the database of patients. Results obtained are given in Table 5. The output is the severity of the disease given in the range of 0 to 10. The last column is an error between estimated output and the observed output.

The average error calculated comes to be 1.1479 for Knee OA for Mamdani method. Similarly the Sugeno model is used for the same database. Table 6 shows the performance of the Sugeno method.

The average error for the Knee OA FIS comes to be 1.6232 for Sugeno method. The results obtained with ANFIS method are shown in Table 7.

Table 6: Results of Knee OA FIS using ANFIS method

Case No.	Doctor Diagnosis (Estimated Output)	ANFIS Diagnosis (Observed Output)	Error (ξ)	Case No.	Doctor Diagnosis (Estimated Output)	ANFIS Diagnosis (Observed Output)	Error (ξ)
1	5	5.1223	0.1429	31	5	5.0000	4.5000
2	3	2.7081	1.0000	32	6	5.5774	4.6545
3	3	3.2055	1.0000	33	2	2.2071	2.0000
4	3	2.1850	2.5000	34	2	3.4160	1.5000
5	3	3.8652	2.5000	35	3	4.6916	2.5000
6	2	2.1005	0.6207	36	8	8.1962	1.0000
7	0	0.0000	0.9981	37	0	0.0000	0.0000
8	3	2.8077	2.5000	38	2	1.9709	0.6207
9	8	7.7284	1.0000	39	2	2.1965	0.1036
10	8	7.2357	1.0000	40	2	1.9610	2.0000
11	3	2.8453	0.7471	41	3	3.9978	2.5000
12	7	7.8656	2.0000	42	0	0.0000	0.0000
13	0	0.0000	0.0000	43	5	4.5126	4.5000
14	4	4.4452	3.5000	44	0	0.0000	0.0000
15	2	3.0583	2.0000	45	0	0.0000	0.0000
16	6	6.0020	4.6799	46	0	0.0000	0.0000
17	2	3.0910	1.5000	47	7	6.9432	2.0000
18	3	3.9285	1.0000	48	0	0.0000	0.0000
19	3	2.8906	2.5000	49	0	0.0000	0.0000
20	4	3.6672	3.5000	50	8	8.0558	1.0000
21	6	5.4062	4.7558	51	0	0.0000	0.0000
22	1	1.3131	3.0000	52	0	0.0000	0.0000
23	0	0.0000	0.0000	53	0	0.0000	0.0000
24	5	5.5047	4.5000	54	5	5.9435	4.5000
25	8	8.0080	1.0000	55	0	0.0000	0.0000
26	8	7.7592	1.0000	56	0	0.0000	0.0000
27	6	3.8069	4.7680	57	4	3.2269	0.0000
28	7	6.5734	2.0000	58	0	0.0000	0.0000
29	8	7.8221	1.0000	59	6	6.6695	4.8000
30	3	3.5716	2.5000	60	0	0.0000	0.0000

With ANFIS model the average error computed was 0.3638. The three models are tested for the database of 60 patients who were suffering from orthopaedic diseases.

5. Discussion

All the three methods are useful in the problem undertaken even though nonlinear characteristic nature of diagnosis process.

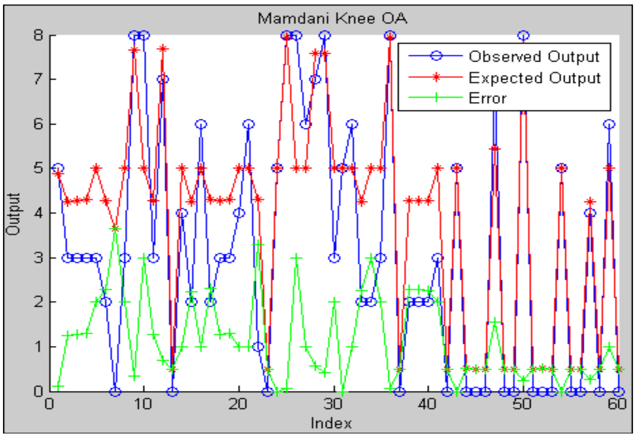

Fig. 5(a) Result for 60 records using Mamdani method for Knee OA Diagnosis

The symptoms described by the patient are normally ill defined, vague, linguistic, and sometimes inconsistent type. The graphs in the Fig 5(a), 5(b), 5(c) show the deviation of observed output from expected output. The Blue color line indicates the Expected output, Green color line shows Observed output, and the Red color line shows the error i.e. difference between these two values.

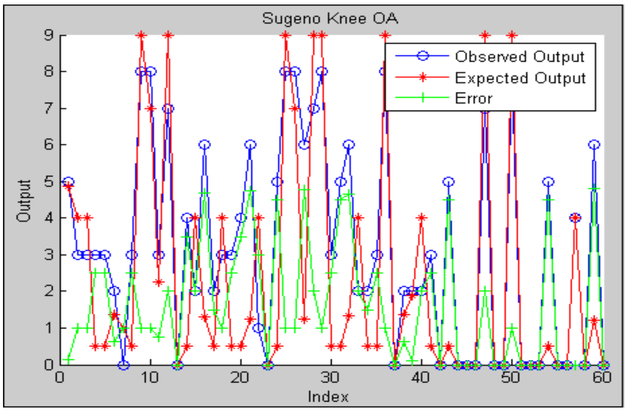

Fig. 5(b) Result for 60 records using TSK method for Knee OA Diagnosis

The experimental result shows that ANFIS model offers best results with average error 0.3638. The performance of these methods is compared with the help of graph displayed in Fig.6.

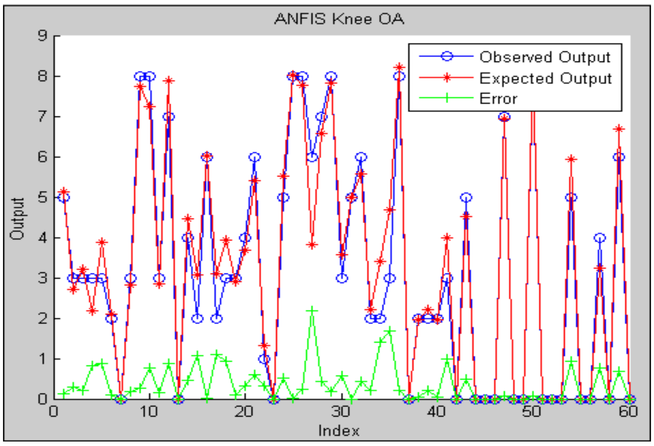

Fig. 5(c) Result for 60 records using ANFIS method for Knee OA Diagnosis

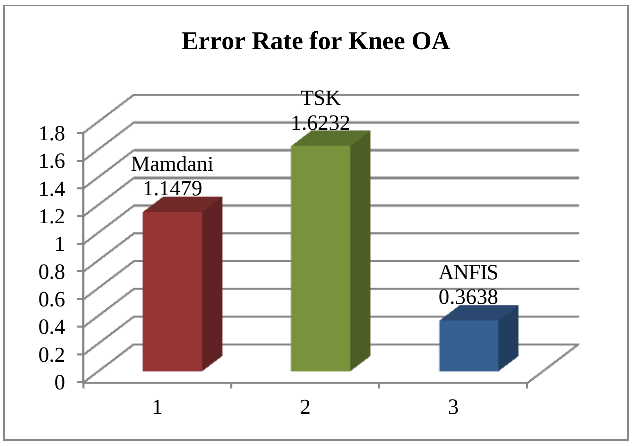

Fig.6 Error Rate of Knee OA using three methods

Conclusion

This paper discus about three methods Fuzzy Inference: Mamdani, Sugeno and ANFIS which have been implemented for the diagnosis of Knee Osteoarthritis disease. The experimental results have shown that the performance of ANFIS is much better as compared to Mamdani and Sugeno method. It is because, ANFIS is perfect blender of Fuzzy and Neural technique, it learns with the specified data. This proves that ANFIS can be efficiently used for diagnosis purpose with accuracy almost 98%. This reveals application potential of ANFIS technique in the process of diagnosis of Knee Osteoarthritis disease.

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