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Fuzzy Regression Model for Knee Osteoarthritis Disease Diagnosis

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Abstract- ***It is a trend now a days to use potential of statistical techniques for medical diagnosis purpose. The novice general medical practitioner always takes a second opinion from other sources, to take a firm decision on his diagnosis. This paper discusses the application of fuzzy regression for the diagnosis of Knee Osteoarthritis.***

1. INTRODUCTION

Automated diagnosis is specially used to diagnose the variety of diseases. The proposed regression model is a computer program that makes prediction based on knowledge obtained from patient database. The goal is to deal with complex real-world decision making problems. Regression Technique can be independently used medical diagnosis. Also it can be combined with Fuzzy approach so it becomes Fuzzy Regression [1]. This work is focused on the diagnosis of Knee Osteoarthritis disease.

Multiple Regression Model can be used for estimating the development time of a software[2],where the author has stated higher accuracy than other methods for estimating. Research demonstrates that fuzzy multiple regression models are better than linear regression equations and fuzzy models. Rosma Mohd Dom [3] has explained the use of Fuzzy Regression models for prediction of Oral Cancer. In [4-7] other applications of Fuzzy Regression are discussed.

The paper is organized as follows: Theoretical background about fuzzy regression is given in section 2. Section 3 explains the design of the system where the fuzzy regression is used for diagnosis the osteoarthritis disease. In the section 4 focuses on the results obtained from the system, discussion on the result is covered in the following section. Section 6 concludes the whole work.

2. FUZZY REGRESSION

In statistics, regression analysis is a statistical technique for estimating the relationships among variables [8]. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. The knowledge of the values of the independent variables enables prediction of the value of the dependent variable or likelihood of the occurrence of an event if the dependent variable is categorical. It is depicted in the Fig 1. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed.

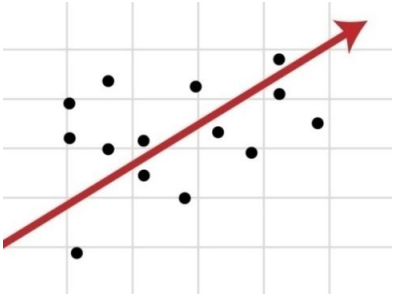

Fig. 1 Regression Technique

There are three kinds of models that fit a fuzzy linear regression equation: (1) fuzzy posibilistic regression, (2) fuzzy least squares regression and (3) fuzzy regression based on interval analysis. The fuzzy least squares regression method is more popular. In the general least square problem, the output of a linear model y is given by the linearly parameterized expression[Zang]

$$y = \theta_1 f_1(u) + \theta_2 f_2(u) + \ldots + \theta_n f_n(u)$$

1.1

where u=[u1,u2,...up]T is the model's input vector, f1,f2,...fn are known functions of u and $\theta_1, \theta_2, \ldots \theta_n$ are unknown parameters to be estimated. In statistics the task of fitting data using a linear model is referred to as linear regression. The equation 1.1 is called as regression function, and the $\theta i's$ are called the regression coefficients.

In this model, the coefficients of regression are fuzzy and observed input and outputs are not fuzzy.

Regression analysis is an estimation method used in finding a crisp relationship between the dependent and independent variables and also used to estimate the variance of measurement error. When the modeling involves finding the relationship between a single input variable and its corresponding output variable, it is known as Simple Linear Regression analysis. Often, simply estimating a one-parameter model is not sufficient. The situation where we have more than one independent variable is known as Multiple Linear Regression.

3. DESIGN OF FUZZY REGRESSION TECHNIQUE FOR MEDICAL DIAGNOSIS

The database of patients is collected who are suffering from Osteoarthritis disease. The diagnosis for Knee Osteoarthritis is based five symptoms. Following is the set of symptoms:

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

If the granularity of the data set is very high and it is nonlinear, generating one linear function would result in greater Error. The aim of precision would be lost. In this case generating multiple linear functions would become a good choice. The data can be divided into groups and for each group one linear function can be generated. Similar kind of data can be kept together to form a group.

The regression technique is applied on the database of patients suffering from Knee Osteoarthritis disease. The database of 60 records is divided in to three groups according to age. The Table 1 shows the distribution of the database of patients.

Table 1: Grouping of Records

Group Name	Number of records
Young (31 to 40)	4
Adult(41 to 60)	36
Old (61 to 120)	20

Algorithm for Generating Regression Equation

Step 1: Accept the symptoms for all patients
Step 2: Assign the symptoms to an array
Step 3: Accept the diagnosis (output)
Step 4: Assign it to an array
Step 5: Construct the set of simultaneous equations by forming the matrix X, and solve for the parameters by using backslash operator values to compute the required coefficients.

The given algorithm is implemented in MATLAB for Adult Group of Knee OA. In this age group there are 36 records, out of those first 10 records are used for generating the coefficients. The remaining records (26) are used for the Testing purpose.

So the coefficients calculated from the given code are

β0 = -0.6679
β1 = 0.0618
β2 =-0.0003
β3 = -0.0179
β4 = 0.0755
β5=-2.2105

The MATLAB code is given below

```
% For Adult Age Group 10 records used for generating the equation and 28
% are used for Testing the equation.
% Assigning the symptoms of 10 patients to each array x1,x2,x3,x4,x5

x1=AdultKneeOAData(1:10,1)
x2=AdultKneeOAData(1:10,2)
x3=AdultKneeOAData(1:10,3)
x4=AdultKneeOAData(1:10,4)
x5=AdultKneeOAData(1:10,5)

% Assignment of Diagnosis(Output) to array y for 10 patient
y=AdultKneeOAData(1:10,6)

% Calculating the Coefficients
 X = [ones(size(x1))   x1   x2  x3  x4  x5];
 a=X\y
```

4. Result

Once the coefficients are generated for the given data set, results are tested for the remaining data. After Testing comparison between the Estimated output and Observed output is given in the Table 2. The column Error in the table shows the deviation of observed output and estimated output.

Though the maximum error is greater than 1, the average error generated is 0. 69. This value is sufficiently small. The Fuzzy Regression yields unique linear equation for whole system in small tolerable average error of 0.69. This validates the successful implementation of Fuzzy Regression Method in the diagnosis of Osteoarthritis.

Table 2 Testing Results of Regression for Knee OA (Adult Group 40 to 60)

Record No.	Estimated Output(y)	Observed Output(Y)	Error(In Absolute)	Record No.	Estimated Output(y)	Observed Output(Y)	Error(In Absolute)
1	2	2.36	0.36	14	2	2.76	0.76
2	3	2.67	0.33	15	3	2.80	0.20
3	0	0.30	0.30	16	2	3.12	1.12
4	0	0.28	0.28	17	0	0.79	0.79
5	0	0.34	0.34	18	4	2.91	1.09
6	3	2.61	0.39	19	3	3.17	0.17
7	3	2.67	0.33	20	0	0.70	0.70
8	3	2.74	0.26	21	4	3.15	0.85
9	0	0.55	0.55	22	3	3.32	0.32
10	3	3.00	0.00	23	0	0.76	0.76
11	0	0.75	0.75	24	4	3.24	0.76
12	0	0.53	0.53	25	6	3.45	2.55
13	2	2.87	0.87	26	6	3.31	2.69

5. Discussion

The fuzzy linear regression technique works well with linear functions. Generating only one linear function would result into high error. So three groups of records are prepared according to Age Criteria. The results discussed here are for adult age group.

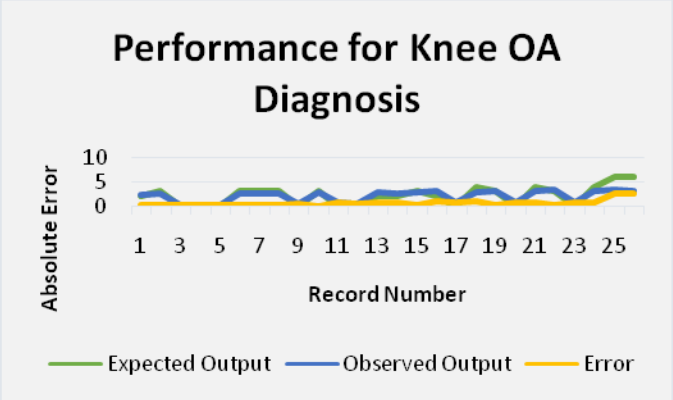

Fig. 2 Result for 26 records using Regression approach for Knee OA Diagnosis

The graph in the Fig 2 shows deviation of observed output from expected output. The graph is drawn in three colors. The Green color line indicates the Expected output, Blue color line shows Observed output. And Yellow color line shows the error i.e. difference between these two values.

When regression technique is used for Knee OA, out of 26 records, the system prompted maximum error of 2.6 for one record i.e. the last record. For the remaining record set, it has shown good accuracy. The average error produced is 0.69.

6. Conclusion

Everyday a General Medical Practitioner handles nearly 100 patients and does a diagnosis of osteoarthritis disease for some cases. For the novice Practitioner it has been found difficult to differentiate between the diseases based on symptoms provided. Medical diagnosis is highly dependent on the information collected from the patient. Fuzzy regression can be a suitable approach for the diagnosis of Knee Osteoarthritis which yields the output with severity of the disease.

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