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# Prediction of blood sugar in people according to such inputs as age, simulation level, BMI, and diet by using of fuzzy control and Adaptive Nero-Fuzzy Inference System(ANFIS)

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**Abstract**
Since diagnosis and control of blood sugar and diabetes in people has been the subject of a large number of research studies, and since a large number of research papers have been written in this regard, in this paper, we found a new method of prediction of blood sugar in 51 participants of the study using fuzzy control and Nero Fuzzy inference model (ANFIS).

***Keywords:*** prediction of blood sugar in people, diabetes, fuzzy control, Adaptive Nero Fuzzy inference system (ANFIS)

## 1. Introduction

All over the world, people who live in cities have less physical activity. On the other hand, the population of world is going up and people are living longer than a few centuries ago. Yet, people are eating less and less healthy food and consume more and more fattening food instead.
Therefore, the inappropriate combination of "little physical activity" on the one hand and "unhealthy food consumption on the other hand" has led to unprecedented progress of diabetes in the world. Blood sugar or diabetes is a disease resulted from inappropriate production and function of insulin in human body. If diabetes is not controlled and cured, it will have deadly side effects, such as heart attack, recurrent infections, eye disease, etc., or it might damage the quality of the life of the sufferer and his or her family. Therefore, predicting this disease in advance can affect the way it can be cured.
Dr. Sarbam and his co-workers began investigating various types of diabetes in 2011 and examined a number of optimal control methods, such as SNAC, ADS, and LQR. SNAC uses neural networks to solve revised non-linear dynamic mathematical equations for solving complex problems.ADS is a method which uses approximate dynamic programming. LQR is a method in which linear quadratic regulator for optimal control is used.
In 2010, Dr. Larry Brown and his coworkers investigated blood sugar control by using insulin and its advantages and disadvantages and examine the appropriate level of insulin used. In 2009, k. Faruque Ali and Radhakant Padhi began using smart feedback strategy to control the level of blood sugar in diabetes. In this strategy, single-comparative networks based on non-linear optimal control have been used. In this paper, we used 51 participants. First, we recorded the participants' blood sugar which had been measured by physician using glucometer. Then, using sogino fuzzy control method and Adaptive Nero Fuzzy inference system (ANFIS) predicted the level of blood sugar and compared it to what had already been measure by physician. We were able to obtain appropriate results.
According to traditional and classical methods of modeling, reasoning, and calculations have two results of ether yes or no, or black or white. In the real world, however, obtaining clear-cut boundaries between phenomena or processes is an arduous one and in a lot of cases, judgments and conclusion based on such calculations would be impossible. in fuzzy theory, however, unlike traditional methods, the boundary between collections has not been as clear cult and judgments are based on such terms as "less" or "more". In other words, in fuzzy systems, the type of modeling has been approximate reasoning and the independence of each item to a collection depends on the amount of its independence on that collection. This view is the basis of fuzzy logic, which has been proposed by Dr. Lotfizadeh. It should be pointed here that the main idea of mamdani controller is explaining process conditions by language variables and use of such variables as the input for control regulations. In sugeno controller, the main idea is writing regulation which has prior fuzzy (mamdani equivalent controller) and absolute results, which are a function of input variables.

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## 2. Prediction of blood sugar in people and applying fuzzy models

Fuzzy system is a system based on knowledge and regulations. At the heart of a fuzzy system exists a knowledge base consisting of fuzzy if-then regulations. The starting point in a fuzzy system is obtaining a collection of fuzzy if-then regulations of the knowledge of experts or the area under investigation. Next level is combining these regulations in a unified system. Different fuzzy systems use different principles and methods for combining these rules. In this section, we use direct mamdani method, Sugeno method, and Adaptive Nero Fuzzy inference system for fuzzy reasoning.

In this paper, our system has four inputs including person's age, BMI, stimulation level, and diet as well as one output which indicates blood sugar in fasting people. Now, based on inputs we have, we are going to predict and obtain blood sugar input.

### 2.1 Adaptive Nero Fuzzy inference system

In the first method called mamdani reasoning, using fuzzy if-then regulations which include six items as approved by the physician, we obtained the following results.According to the inputs which include 4 items and their outputs, as indicated below with their triangular membership function: The curve for membership function is as shown in Fig.1, in which x axis represents people's age from 17 to 46 as young, 35 to 65 as yadult, and above 60 as senior. The y axis represents membership function of young age, adult age, and senior's age.

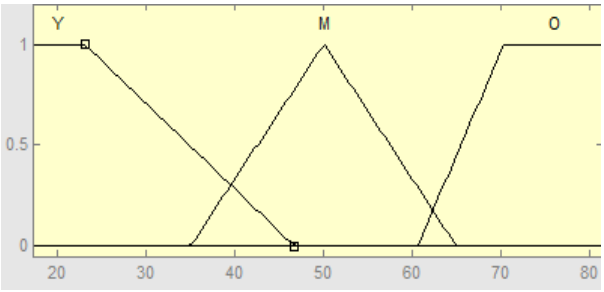


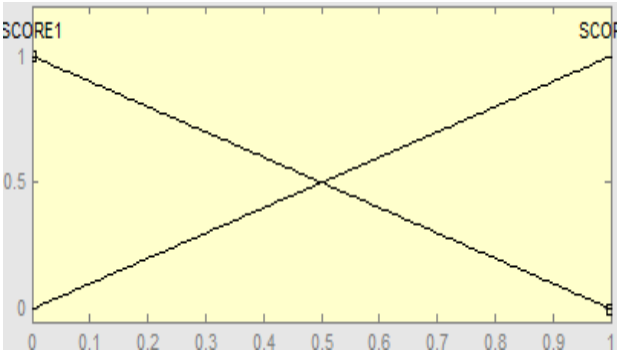

Fig. 1 Curve of membership function of people's age

The curve for membership function BMI is as shown in Fig.2, in which horizontal axis BMI less than 22/5kg/m2 is low, between 20(kg/m2) and 28 ($k_g / m^2$) is medium, between 25 ($k_g / m^2$) and 34 ($k_g / m^2$) is overweight, and above 29 ($k_g / m^2$) is beyond overweight. The vertical axis represents membership function of low, medium weight, overweight, and beyond overweight.

Fig. 2 Curve of BMI membership function for people


The curve for membership function of the activity level has been shown in Fig.3, in which walking for less than 30 minutes has been shown with score 1 and walking for more than 30 minutes has been shown with score2. Here we consider the horizontal axis in an interval of 0 and 1.

Fig . 3 Curve of membership function of people's level of activity




The curve of membership function for diet has been scored and shown in Fig. 4. In this Figure, on the horizontal axis, b represents the use low amount of sugar, c represents medium use of sugar, and a represents high amount of sugar use. This axis has an interval from zero to two, in which between zero to one (Mg/dl) represents low amount of sugar use, between 0.5 (Mg/dl) to 1.5(Mg/dl) represents medium use of sugra, and above one (Mg/dl) represents high amount of sugra use.

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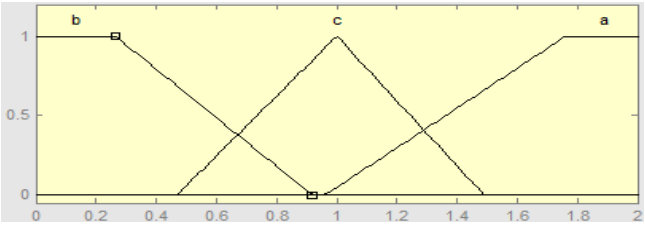


Fig . 4 Curve of membership function of people

Our target output is the blood sugar of fasting people. 60<normal blood sugar<105 which, according to the physician, in 105<border line <126 is border line or above. According to 51 participants of the study and our target inputs, the if-then regulations as the physician has deem have been defined as below:

1- If a young person with normal BMI and low level of physical activity has has low use of sugar, then the person's blood sugar in fasting condition will be low.
2- If a young person with overweight BMI and low physical activity has medium amount of sugar use, then the person's blood sugar in fasting condition will be normal.
3- If a young person with overweight BMI and low physical activity has high amount of sugar use, then the person's blood sugar in fasting condition will be normal.
4- If a young person with overweight BMI and low physical activity has medium amount of sugar use, then the person's blood sugar in fasting condition will be normal.
5- If an adult with overweight BMI and low physical activity has medium amount of sugar use, then the person's blood sugar in fasting condition will be within border line.
6- If a elderly person with normal BMI and low physical activity has low amount of sugar use, then the person's blood sugar in fasting condition will be high.

All the above regulations have been approved by the physician

## 3. Simulation result of fuzzy models

In the first method which is a mamdani reasoning method, the view of FIS editor is as Fig. 5:

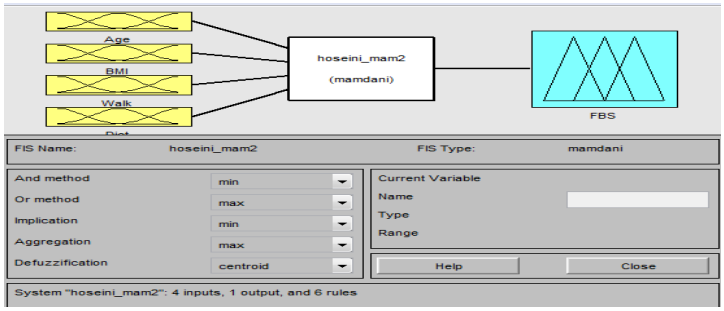


Fig . 5 Views of FIS editor (mamdani method)

Regulation screen displays a general view of the fuzzy system. In this figure every line indicates one regulation. The first four columns indicate inputs and the name of each variable as well as its amount has been indicated above each column. The fifth column indicates output of each regulation.

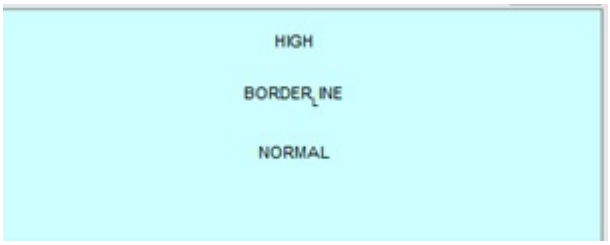


Fig .6 regulation screen

In the second method, calld Sugeno, the view of the editor is as Fig .7

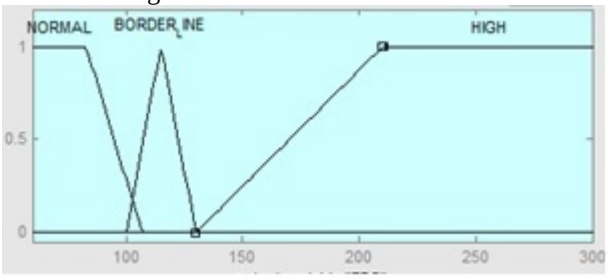


Fig .7 View of FIS editor (fuzzy sugeno method)

In these two methods our target output is as follow:

Fig .8 Curve of membership function of blood sugar of fasting people in mamdani reasoning method

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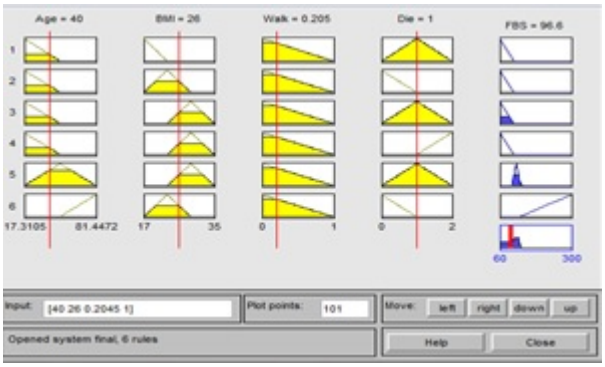


Fig .9 Curve of membership function of blood sugar of fasting people in Sugeno method

Finally, using Nero Fuzzy inference system (ANFIS), a comparison has been made, which gives us more clear answers. Fig. 10 indicates the ANFIS structure:

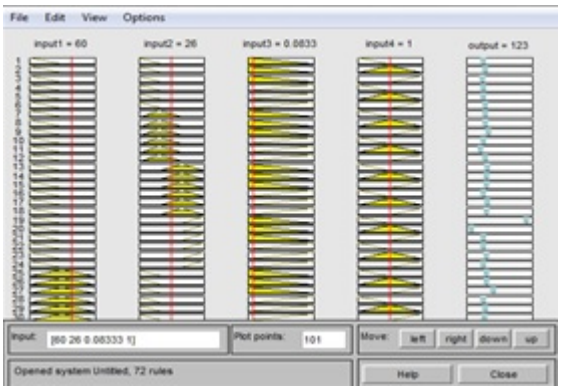


Fig .10 structure of ANFIS model according to target inputs and output

It should be mentioned here that in this study we considered 70 % of data as Training data and the rest as Testing data.

In Fig. 11 and 12 the results of Nero Fuzzy inference model (ANFIS) in training and testing condition has been indicated. As it can be seen, the performance of the model in both training and testing is close to 100%.

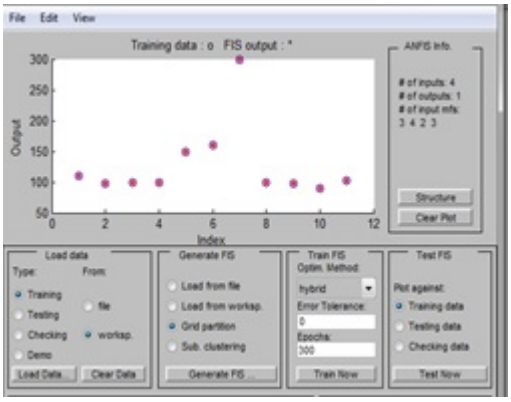


Fig .11 Neuro-fuzzy model in Training stage

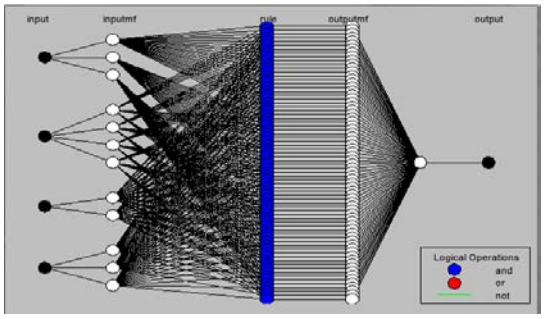


Fig .12 Neuro-fuzzy model in Testing stage

Also in the Fig. 13 the regulation screen including 72 regulations has been indicated.

Fig .13 Regulation screen in Nero Fuzzy inference model (ANFIS)

Now, in table 1 the blood sugar measured by physician through glucometer and blood sugar measured by fuzzy control (mamdani reasoning method- sugeno fuzzy method and Nero Fuzzy inference model (ANFIS)

| ***Number*** | ***Sex*** | ***FBS obtained by physician through glucometer*** | ***FBS obtained through mamdani reasoning*** | ***FBS obtained through sugeno fuzzy*** | **FBS obtained through ANFIS** |
|---|---|---|---|---|---|
| 1 | women | 89(Normal) | 76(Normal) | 75(Normal) | 88.9(Normal) |
| 2 | women | 100(Normal) | 81(Normal) | 82.5(Normal) | 100(Normal) |
| 3 | women | 105(Normal) | 98(Normal) | 103(Normal) | 105(Normal) |
| 4 | men | 101(Normal) | 78(Normal) | 75(Normal) | 98.8(Normal) |
| 5 | men | 109(Borderline) | 114(Borderline) | 110(Borderline) | 109(Borderline) |
| 6 | women | 170(High) | 229(High) | 211.8(High) | 167(High) |

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## 4. Conclusion

In this paper, prediction of blood sugar in 51 participants according to inputs and by using fuzzy control (mamdani reasoning _sugeno fuzzy method) and Nero Fuzzy inference model (ANFIS) was made. According to table 1, it was seen that Nero Fuzzy inference model (ANFIS) provides us with much closer answers to physician's answers.

## References

[1] Saadet Ulas Acikgoz, Urmila M. Diweka, "OPTIMAL CONTROL OF DIABETES MELLITUS UNDER TIME DEPENDENT UNCERTAINTIES," Bell System Technical Journal, 2012, vol. 51, pp. 1611–28.

[2] D. Subbaram Naidu1, Tyrone Fernando and K. Renee Fister , "Optimal control in diabetes
," OPTIMAL CONTROL APPLICATIONS AND METHODS, Optim. Control Appl. Meth. 2011; 32:181–184.

[3] Larry Brown and Elazer R. Edelman, "Optimal Control of Blood Glucose" , Published 14 April 2010; Volume 2 Issue 27 27ps18.

[4] Victor M. Montori, and Merce` Ferna´ ndez-Balsells, "Glycemic Control in Type 2 Diabetes", Annals of Internal Medicine Journal, 21 April 2009.

[5]Ali, Faruque SK and Padhi, Radhakant, "Optimal blood glucose regulation of diabetic patients using single network adaptive critics", Optimal Control Applications and Methods, 32 (2). pp. 196-214, 26 Apr 2011

[6] A. Honeycutt, J.P. Boyle, K.R. Broglio, T.J. Thompson, T.J. Hoerger, L.S. Geiss, K.M. Venkat, A dynamic Markov model for forecasting di-abetes prevalence in the United State through 2050, Helath Care Man-agement Science 6, 155-164, 2003.

[7] C. Peng, Ch. Zhang, Inde¯nite Linear Quadratic Optimal control Prob- lem for singular discrete-Time system: Krein Space Method, Acta Au-tomatica Sinica, 33, 6, 635-639, 2007.

[8] Irma Y. Sánchez Chávez, Rubén Morales-Menéndez Rubén Morales-Menéndez, "Glucose optimal control system in diabetes treatment",Glucose optimal control system in diabetes treatment, Volume 209, Issue 1, 1 March 2009, Pages 19-30