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Fuzzy Cognitive Maps Approach to Identify Risk Factors of Diabetes

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ABSTRACT

Fuzzy Cognitive Maps (FCM) have been applied in many fields successfully to show the causes and effect relationship. In this research work, the relationship between risk factors and symptoms of Diabetes has been analyzed with the help of FCM. FCM is a fuzzy-graph modeling approach based on expert's opinion. This is the non-statistical approach to study the problems with imprecise information. This paper has foursections. Section one discusses the background of this study, Section two talk about related work, the materials (literature survey of FCM), methods and results analysis are given in Section three, Final section derives the conclusion based on study.

Keywords: Diabetes, Fuzzy Cognitive Maps (FCM), Algorithm of FCM.

1. Background of study

The incidence of diabetes has doubled in the last ten years in the worldwide. About 200 million people are infected and about six percent increase in the annual prevalence of diabetes in the world with more than 7.1 million people in Bangladesh are infected with this disease, 8.4% of the adult population affected by the disease. According to research published in WHO bulletin in 2013, it is more than 10 million. The number will be 13.6 million in 2040, predicts several sources including IDF Diabetes Atlas. Nearly half of the population with diabetes, 51.2%, don't know that they have diabetes and don't receive any treatment.Bangladesh is home to a 161 million population, according to the latest census report. During 90s, the country has a relatively low diabetes affected population. In 1995, it was only 4% which grew to 5% in 2000 and 9% during the period 2006 to 2010. According to the International Diabetes Federation, the prevalence will be 13% by 2030.The most alarming news is that a growing number of children and young people are developing diabetes. There are a couple of reasons behind this rapid growth of diabetes in Bangladesh. Selim, an Assistant Professor at Department of Endocrinology, Bangabandhu Sheikh MujibMedical University, Bangladesh, says lack of awareness, inconsiderate lifestyle, and lack of preventative initiatives from the government are among the major reasons behind this growth. Selim goes on: Bangladesh currently is among the countries that are considered to be most vulnerable to diabetes[1].

[1]http://futurestartup.com/2016/10/25/why-is-diabetes-on-the-rise-in-bangladesh/

In this work, Fuzzy Cognitive Maps are proposed which relates symptoms and risk factors of diabetic patient based on the expert's medical knowledge that is taken to identify the diabetes and the results are evaluated.

2. Related work

Radha et al [7] proposed the fuzzy logic approach for diagnosis of diabetic where the fuzzy logic is taken as a mathematical tool to deal the uncertainty and imprecision typical of human reasoning. In this approach the knowledge is expressed in linguistic way. Fuzzy membership values are represented using different symptoms to form the relations. Fuzzy relation is applied in few patients' clinical databases to diagnose whether the patient is diabetic or not.Sapna et al. [10,11] proposed fuzzy relational equation for preventing diabetic cardiovascular disease and diabetic neuropathy. In these methods the risk factors and symptoms of diabetic neuropathy and cardiovascular diseases are used to make the fuzzy relation equation. From the results of the proposed methods it is observed that the expert's opinion and the clinical research opinion are found to be similar which satisfies the fuzzy relations. Rama Devi et al [8] proposed a new design methodology of a fuzzy knowledgebase system to predict the risk of diabetic nephropathy in terms of Glomeruler Filtration Rate (GFR). This fuzzy knowledgebase captures all the variations of the symptoms and so, it will be useful to infer the exact stage of renal patient as per the expert's knowledge. The proposed method is used to take proper decision at the right time for giving various types of treatments which ultimately reduces the rate of mortality. Rajeswari et al [9] investigated a variation to preliminary inquiry information obtained from patients of a diabetic and research center using a fuzzy relation based model. This approach is an attempt to closely replicate a physician's insight of symptom-disease associations and his approximate-reasoning for conclusion on real time data sets. This method proves to be highly efficient with good accuracy as it models the realistic or linguistic way of the patient. This system also stated that it could assist the diabetologist as a support for classification and further analysis. But in the above system features collected in stage 1 are not satisfied to classify Type 2 diabetic patient from others. Parastoo RAHIMLOO and Ahmad JAFARIAN [6] suggest Artificial Neural Network, Logistic Regression Statistical Model and Combination of them to predict diabetes. In this work, FCM is used to identify all types of diabetic patient based on different risk factors and symptoms.

3. Materials and methods

3.1. Introduction to diabetes

Diabetes or diabetes mellitus, is a metabolic disorder (metabolic) in the body. In this disease is destroy the ability to produce insulin in the patient's body or the body becomes resistant to insulin the and therefore the produced insulin cannot perform its normal function. The primary role of insulin to lower blood sugar by different mechanisms. There are two main types of diabetes. In Type I diabetes, destruction of beta cells in pancreatic leads to impaired insulin production and in type II, there is a progressive insulin resistance in the body and eventually may lead to the destruction of pancreatic beta cells and defects in insulin production. In type II diabetes it is known that genetic factors, obesity and lack of physical activity have an important role in a person.

3.1.1.Diabetes categories

Diabetes is an epidemic disease that occurs due to the decrease or absence of insulin in the body. There are different types of diabetes that usually are distinguished at diagnosis; so determine the type of diabetes is dependent on conditions that their disease manifest itself. Since the old division two types of diabetes is insulin-dependent and non-insulin dependent, the new classification of diabetes was developed by the America Diabetes Association: Type I diabetes, type II, gestational diabetes and other types.

3.1.2.Type 1 diabetes

Type I diabetes (insulin dependent diabetes mellitus) is a chronic disease that occurs when the pancreas (Pancreas), releases the small amount of insulin (a hormone that is required for importing sugar into the cells for energy production) or doesn't make insulin. Several factors, including genetics and infection with certain viruses can cause type I diabetes. Although type 1 diabetes usually occurs in childhood and adolescence, but adults are also susceptible to this disease.

3.1.3. Type 2 diabetes [6]

Type 2 diabetes (adult diabetes or Non-insulin-dependent diabetes), is one of the most common types of diabetes and constitutes about 90 percent of the patient. Unlike type 1diabetes, the body produces insulin in type 2 diabetes, but produced insulin by the pancreas is not enough or body does not use insulin properly. When there is not enough insulin or the body does not use insulin, glucose (sugar) in the body, cannot move to the body's cells and causes to an accumulation of glucose in the body and the body would be in trouble and deficiencies. Unfortunately, there is no cure for this disease, but with the healthy diet, exercise and keep fit, can enhance it. If diet and exercise are not enough, you need medication or insulin treatment. Figure 1 is an analysis of diabetes.

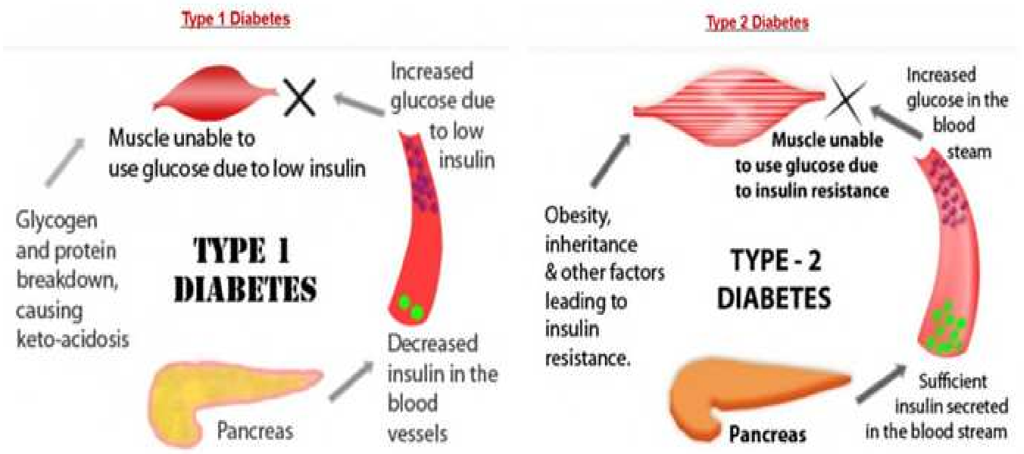

Figure 1[6]: Analysis of Diabetes

3.2. Fuzzy cognitive map

3.2.1. Introduction

In 1976, Political scientist R. Axelord has introduced a model called Cognitive Maps (CM) [3, 4] to study decision making in social and political systems. CM is digraph designed to represent the causal assertion and belief system of a person (or group of experts) with respect to a specipic domain and uses that statement in order to analyze the effect of a certain choice on a particular objective. Fuzzy Cognitive Map (FCM), introduced by Bart Kosko in 1986 [3], extends the idea of CM by allowing the concepts to be represented linguistically with an associated fuzzy set. FCM can successfully represent knowledge and human exprence, introduced concept to represent the essential elements and the cause and effect relationships among the concepts to model the behavior of any system. It is very convenient, simple and powerful tool, which is used in numerous fields social, economical and medical etc. In this work, we recall the notion of Fuzzy Cognitive Maps (FCM), which was introduced by Bart Kosko.

3.2.2. Preliminaries

Fuzzy Cognitive Maps (FCM) are more applicable when the data in the first place is an unsupervised one. It model the world as a collection of classes and causal relations between classes. Some important definition of FCM are discussed below:

3.2.3 Definition [1, 3,12]

A **FCM** is a directed graph with concepts like polices, events etc, as nodes and causalities as edges. It represent causal relationship between concepts. If increses (or decreses) in one concept/ node leads to increase (or decrease) in another concept, we give the value 1; otherwise we give the value -1. If there exists no relation between concepts the value 0 is given. Let $C_1, C_2, \dots \dots \dots, C_n$ be the nodes of the FCM. Suppose that the directed graph is drawn using weights $e_{ij} \in \{0, 1, -1\}$. The matrix E is defined by $E = (e_{ij})$; where e_{ij} is the weight of the directed edge C_iC_j. E is called the **adjacency matrix** of the FCM. All matrices associated with an FCM are always square matrices with diagonal entries equal to zero.

3.2.4. Definition[1, 3,12]

Let $C_1, C_2, \dots \dots \dots, C_n$ be the nodes of the FCM. Let $A = \{a_1,\ a_2, \dots \dots \dots, a_n\}$, where $a_i \in \{0, 1\}$. A is called the **instantaneous state neutrosophic vector** and it denotes the ON-OFF state position of the node at an instant

$$a_i = \begin{cases} 0\ if\ a_i\ is\ OFF\ (no\ effect) \\ 1\ if\ a_i\ is\ ON\ (has\ effect) \end{cases}$$

3.2.5. Definition[1, 3,12]

Let $C_1, C_2, \dots \dots \dots, C_n$ be the nodes of the FCM. Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \dots \dots \dots, \overrightarrow{C_iC_j}$ be the edges of the FCM. Then the edges form a directed cycle. An FCM is said to be **cyclic** if it possesses a directed cycle. An FCM is said to be **acyclic** if it does not possess any directed cycle.

3.2.6. Definition[1, 3, 12]
An FCM with cycle is said to have a feedback. Whe there is a feedback in the FCM i.e. when the causal relations flow through a cycle in a revolutionary manner the FCM is called a **dynamical system**.

3.2.7. Definition[1, 3, 12]
Let $\overrightarrow{C_1C_2}, \overrightarrow{C_2C_3}, \dots \dots \dots, \overrightarrow{C_{i-1}C_i}$ be cyclic when C_i is switched on and if the causality flow through the edges of a cycle and if it again causes C_i, we say that the dynamical system goes round and round. This is true for any node C_i, for $i = 1, 2, \dots \dots \dots, n$, the equilibrium state for this dynamical system is called the **hidden pattern**.

3.2.8. Definition[1, 3, 12]
If the equilibrium state of a dynamical system is a unique state vector, then it is called a **fixed point**. Consider the FCM with $C_1, C_2, \dots \dots \dots, C_n$ as nodes. For example, let us start the dynamical system by switching on C_1. Assume that the FCM settles down with C_1 and C_n ON, i.e. the state vector remain as $(1, 0, 0, \dots \dots \dots, 1)$, this state vector is called fixed point.

3.2.9. Definition[1, 3, 12]
If the FCM settles with a state vector repeating in the form $A_1 \to A_2 \to \cdots \dots \dots A_i \to A_1$, then the equilibrium is called a limit cycle of the FCM.

3.2.10. Definition[1, 3, 12]
Suppose $A = (a_1, a_2, \dots \dots \dots, a_n)$ is a vector which is passed into a dynamical system E. Then $AE = (a_1', a_2', \dots \dots \dots, a_n')$, after **thresholding and updating** the vector, suppose we get $(b_1, b_2, \dots \dots \dots, b_n$. We denote that by $(a_1', a_2', \dots \dots \dots, a_n') \hookrightarrow (b_1, b_2, \dots \dots \dots, b_n)$. Thus the symbol $\hookrightarrow$ means the resultant vector has been threshold and updated.

3.3. Algorithm in induced fuzzy cognitive map [4,12]
The Induced Fuzzy Cognitive Map (IFCM) focuses on the algorithm of the FCM which works on unsupervised data to derive an optimistic solution. To get such optimistic solution in the problem with unsupervised data, the following steps must be followed:
Step 1: Collect the nodes for the given problem, which is unsupervised data.
Step 2: Draw the directed graph for the model.
Step 3: From the FCM, obtain the connection matrix E. In this matrix the number of rows equal to the number of steps to be performed.
Step 4: Consider the state vector $V(k_1)$ by setting the first component of this vector C_1 in ON position and the rest of the components in the OFF position.
Step 5: Calculate $M = C_1 \times E$. At each stage the state vector is updated and threshold. The symbol $\hookrightarrow$ represent the threshold value for the product of the result. The threshold value is calculated from M by assigning the value 1 when $x_i > 0$ and 0when $x_i < 0$.
Step 6: Each component in the C_1 vector is taken separately and the product of the given matrix is calculated. Find out the vector y_1, which has the maximum number of one's (1).
Step 7: Considered as fixed point when the same threshold value occurs twice and the iteration gets terminated.

Step 8: Set the vector C_2 in ON state and the rest of the components in OFF state. Continue the calculation discussed in steps 4 to 7.
Step 9: Continue the above process for all the remaining state vector C_n and find out the hidden pattern.

3.4. Adaptation of FCM to the problem

Here the illustration of the dynamical system for the risk factors and symptoms of diabetesis a very simple model. At the very first stage we have taken the following ten arbitrary attributes $(H_1, H_2, H_3, \dots \dots \dots, H_6,\ S_1, S_2, S_3, \dots \dots \dots,\ S_6)$. It is not a hard and first rule we need to consider only these ten attributes. One can increase or decrease the number of attributes according to needs. The following attributes related to the risk factors and symptoms of diabetes are taken as the main nodes for study:
H1: High blood pressure
H2: Smoking / Other Tobacco use
H3: Overweight and obesity people
H4: Abnormal blood fats
H5: Inactive life style
H6: Old Age

S1 : Swelling of legs and ankles
S2: Chest pain
S3: Dyspnoea (shortness of breath)
S4: Dizziness
S5: Less blood flow
S6: Blurring vision

3.5. The directed graph related to the risk factors and symptoms of diabetes:

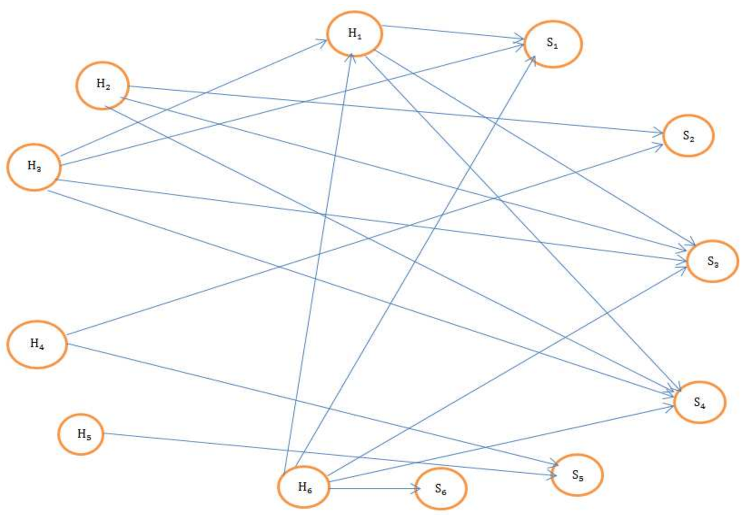

Figure 2: Directed Graph

3.6. Implementation of FCM model to the study

The connection or adjacency matrix M is obtained by taking risk factors $H_1, H_2, H_3, \dots \dots \dots, H_6$ as the rows and symptoms $S_1, S_2, S_3, \dots \dots \dots,\ S_6$ as the columns, assigning values as 1, if there is any relation between nodes and 0, if there is no relation between nodes as follows:

$$M = \begin{array}{c} \\ \mathrm{H1} \\ \mathrm{H2} \\ \mathrm{H3} \\ \mathrm{H4} \\ \mathrm{H5} \\ \mathrm{H6} \end{array} \begin{array}{c} \begin{array}{cccccc} \mathrm{S1} & \mathrm{S2} & \mathrm{S3} & \mathrm{S4} & \mathrm{S5} & \mathrm{S6} \end{array} \\ \begin{pmatrix} 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 1 \end{pmatrix} \end{array}$$

Let us start with the node C_1 is in the ON state i.e. High blood pressure and all other nodes are in the OFF condition. Input the vector

$$A_1 = (1\ 0\ 0\ 0\ 0\ 0\ )$$

The effect of A_1 on the dynamical system M is given by

$A_1M = (1\ 0\ 1\ 1\ 0\ 0\ ) = A_2$ `(Say)

$A_2M = (2\ 1\ 2\ 2\ 1\ 0\ ) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = A_3$ (Say)

A_3M=$(2\ 2\ 3\ 3\ 2\ 0\ ) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = A_4 = A_3$

Where $\hookrightarrow$ denotes the thresholding and updating of the resultant state vector.

The hidden pattern is the fixed point given by $(1\ 1\ 1\ 1\ 1\ 0\ )$ which implies that High blood pressure influences all other attributes except Blurring vision.

Again, let us start with the node C_2 is in the ON state i.e. Smoking / Other Tobacco useand all other nodes are in the OFF condition. Suppose the input vector

$$B_1 = (0\ 1\ 0\ 0\ 0\ 0\ )$$

The effect of B_1 on the dynamical system M is given by

$B_1M = (0\ 1\ 1\ 1\ 0\ 0) = B_2(Say)$

$B_2M = (1\ 2\ 2\ 2\ 1\ 0) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = B_3$ (Say)

B_3M=$(2\ 2\ 3\ 3\ 2\ 0\ ) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = B_4 = B_3$

The hidden pattern is the fixed point given by $(1\ 1\ 1\ 1\ 1\ 0\ )$ which declares that all but last attributes are influenced by Smoking / Other Tobacco use .

Again, consider the nodes C_3 is in the ON state i.e. Overweight and obesity people and all other nodes are in the OFF condition. Suppose the input vector

$D_1 = (0\ 0\ 1\ 0\ 0\ 0)$

Now product of D_1 and M is calculated,

$D_1M = (1\ 0\ 1\ 1\ 0\ 0\ ) = D_2$ (Say)

$D_2M = (2\ 1\ 2\ 2\ 1\ 0\ ) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = D_3$ (Say)

$D_3M = (2\ 2\ 3\ 3\ 2\ 0\ ) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = D_4 = D_3$

So, $(1\ 1\ 1\ 1\ 1\ 0\ )$ is the hidden pattern that means all except last attributes come to ON state.Now, Suppose that C_4 is in the ON state i.e. Abnormal blood fats and all other nodes are in the OFF condition. Suppose the input vector

$E_1 = (0\ 0\ 0\ 1\ 0\ 0)$

$E_1M = (0\ 1\ 0\ 0\ 1\ 0\ ) = E_2$(Say)

$E_2M = (0\ 1\ 1\ 1\ 1\ 0\ ) = E_3$ (Say)
$E_3M = (1\ 2\ 2\ 2\ 2\ 0) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = E_4$ (Say)
$E_4M = (2\ 2\ 3\ 3\ 2\ 0\ ) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 0\ ) = E_5 = E_4$
So, $(1\ 1\ 1\ 1\ 1\ 0\ )$ is the hidden pattern that means all except last attributes come to ON state.Again, consider the nodes C_5 is in the ON state i.e. Inactive life style and all other nodes are in the OFF condition. Suppose the input vector
$F_1 = (0\ 0\ \ 0\ 0\ 1\ 0)$
$F_1M = (0\ 0\ \ 0\ 0\ 1\ 0) = F_2 = F_1$
So, $(0\ 0\ \ 0\ 0\ 1\ 0)$ is the hidden pattern that means only the fifth node come to ON state. Finally, consider the nodes C_6 is in the ON state i.e. Old Ageand all other nodes are in the OFF condition. Suppose the input vector
$G_1 = (0\ 0\ \ 0\ 0\ 0\ 1\ )$
$G_1M = (1\ 0\ 1\ 1\ 0\ 1) = G_2$(Say)
$G_2M = (3\ 1\ 3\ 3\ 1\ 1) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 1\ ) = G_3$ (Say)
$G_3M = (3\ 2\ 4\ 4\ 2\ 1) \hookrightarrow (1\ 1\ 1\ 1\ 1\ 1\ ) = G_4 = G_3$
So, $(1\ 1\ 1\ 1\ 1\ 1\ )$ is the hidden pattern that means all attributes come to ON state i.e. at the Old age, you may face all types of problems mentioned here.
All the results are shown in the following table:

Sl No.	Input	Fixed point
1.	(1 0 0 0 0 0)	(1 1 1 1 1 0)
2.	(0 1 0 0 0 0)	(1 1 1 1 1 0)
3.	(0 0 1 0 0 0)	(1 1 1 1 1 0)
4.	(0 0 0 1 0 0)	(1 1 1 1 1 0)
5.	(0 0 0 0 1 0)	(0 0 0 0 1 0)
6.	(0 0 0 0 0 1)	(1 1 1 1 1 1)

Table 1:

4. Conclusion

From the above result analysis we may conclude that the diabetic condition of patient is badly affected by risk factors, when the patient crosses the adult age. Overweight and obesity is in the second risk, followed by smoking, due to increase in blood pressure.
According to the expert's and clinical research opinion, the diabetic mellitus can be controlled by regular check-up of blood sugar and proper control with medicine and by monitoring regular blood pressure and regular tests of heart function. Prevention on weight gain by promoting salt restricted fat-free diet and regular exercise. A special test of fat content "Lipid Profile" if available may be done. It indicates the magnitude developing heart disease. By controlling smoking and drinking of alcohol the risk factor of heart disease could be reduced.

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