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Fuzzy Cognitive Maps to Study the Fact Behind Homelessness in Bangladesh

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ABSTRACT

This paper deals with the impact of social factors on homelessness in Bangladesh using Fuzzy Cognitive Maps (FCM). The objective of this research work is to find out the most influential factor causing homelessness in Bangladesh. This paper has five sections. 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, Section four presents measure of centrality for analyzing FCM, Final section derives the conclusion based on study.

Keywords: Homelessness, Fuzzy Cognitive Maps (FCM), Algorithm of FCM, Measure of Centrality.

1. Introduction

Homelessness is a complex social problem with a variety of underlying economic and social factors such as poverty, lack of affordable housing, uncertain physical and mental health, addictions, and community and family breakdown. These factors, in varying combinations, contribute to duration, frequency, and type of homelessness. To be fully homeless is to live without shelter; however, many experience partial homelessness that can include uncertain, temporary, or sub-standard shelter. Homelessness is difficult to define, thus governments struggle with uncertainty when creating and implementing policies they hope will effectively manage or eradicate this problem.

A study in Bangladesh in 1995 [4, 9] defined the homeless as people who sleep on streets, railway terminals and platforms, bus-stations, parks and open spaces, religious centers, construction sites, around graveyards, and in other public spaces with no roof.

Understanding the interplay between various social factors is the main motivation behind this research project.

2.Related work

Shoma (2010) [4] has worked on homeless situation of Dhaka Bangladesh. The study of Ahmed et al. (2011) [9] discussed on the Lives and Livelihoods on the Streets of Dhaka City. Ashley and Carney [5] have told about Sustainable Livelihoods: Lesson from early experience, DFID, London.

The writing of Bannerjee and Das [6] presented on The Nature, Extent and Eradication of Homelessness in India. Garg [8] has worked on a Night shelters programs for homeless: A case study of Delhi. However, to the best of our knowledge none of the earlier studies analyzed the homelessness problem of Bangladesh based on mathematical tools. So, this study will try to find the fact behind homelessness in Bangladesh using FCM and measure of centrality.

3. Fuzzy cognitive map

3.1. Introduction

In 1976, Political scientist Axelord has introduced a model called Cognitive Maps (CM) [3, 7] 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 [7], 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. 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:

Definition 3.2.1. [1, 3, 10] 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.

Definition 3.2.2. [1, 3,10] 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

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

Definition3.2.3. [1, 3,10] 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.

Definition 3.2.4. [1, 3, 10] 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**.

Definition 3.2.5. [1, 3, 10] 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**.

Definition 3.2.6. [1, 3, 10] 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.

Definition 3.2.7. [1, 3, 10] 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.

Definition 3.2.8. [1, 3, 10] 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 [3, 4, 10]

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 $x_i \leq 0$.
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.A simple FCM of heart disease illustrated in Figure 1.

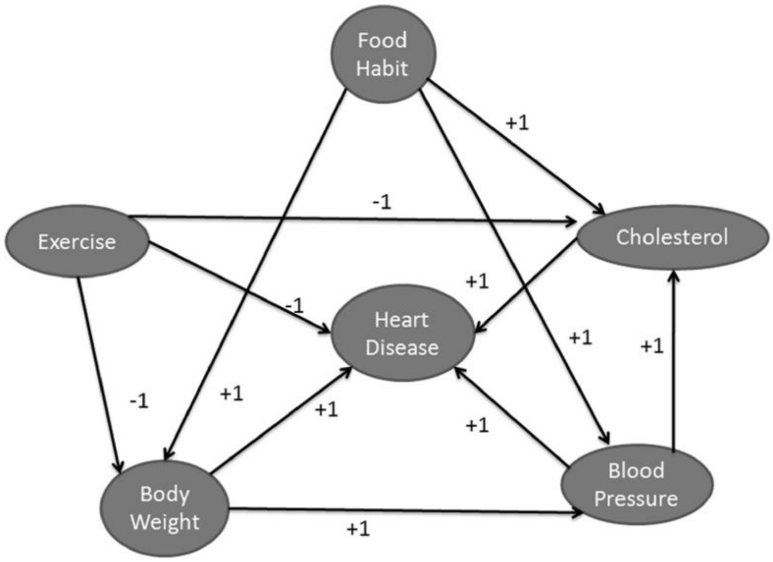

Figure 1: Example of a simple FCM to assess heart disease

The concepts, determined empirically, which relate to heart disease in this model include: exercise (E), food habits (FH), cholesterol (C), blood pressure (BP), and body weight (BW). The links, directionally joining the concepts, represent the fuzzy causal relationships. The connection or adjacency matrix, M for the heart disease problem is as follows:

M=

	E	FH	C	BW	BP	HD
E	1	0	1	1	0	1
FH	0	1	1	1	1	0
C	0	0	1	0	0	1
BW	0	0	0	1	1	1
BP	0	0	1	0	1	1
HD	0	0	0	0	0	0

Following our heart disease example, consider: the concept, E, is active for some individual. Therefore, E=1. No information is available for all other concepts in the map. Therefore, FH=0, C=0, BW=0, and BP=0. This is expressed by a vector C_1 = (1,0,0,0,0,0). According to the algorithm of FCM, the processing is listed in Table 1.

C_1W	=	(1, 0, 1, 1, 0, 1)			=	C_2	
C_2W	=	(1, 0, 2, 2, 1, 3)	↪	(1, 0, 1, 1, 1, 1)	=	C_3	
C_3W	=	(1, 0, 3, 2, 2, 4)	↪	(1, 0, 1, 1, 1, 1)	=	C_4	$\Leftrightarrow C_3$

Table 1: FCM processing when exercise = 1

The symbol ↪indicates the threshold value for the product of the result. The above results demonstrate that it takes four steps for the system to converge to a stable state (limit cycle). The vector C_4 demonstrates that the active E has direct influence on C, BW, BP, and HD.

3.4. Adaptation of FCM to the problem

Here the illustration of the dynamical system for the social factors of homelessness is a very simple model. At the very first stage we have taken the following sixteen arbitrary attributes $(P, U, E, I, A, SI, FB, MI, NGO, Pop, GA, CH, RS, C, H)$.It is not a hard and first rule we need to consider only these sixteen attributes. One can increase or decrease the number of attributes according to needs. The following attributes related to the social factors of homelessness are taken as the main nodes for study:

CJSI: Criminal Justice System Involvement
P: Poverty
U: Unemployment
E: Education
I: Income
A: Addiction
SI :Social Isolation
FB: Family Breakdown
MI: Mental Illness
NGO : Non-Government Organization
Pop: Population
GA: Government Assistance
CH: Cost of Housing
RS: Rental Subsidy
C: Crime
H: Homelessness

3.5. The directed graph related to the risk factors of homelessness

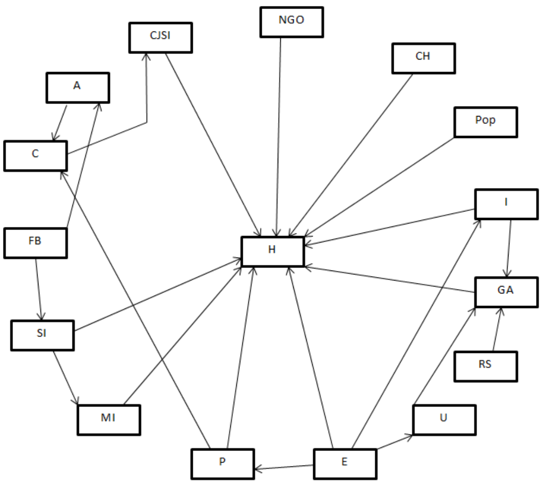

Figure 2: Directed Graph

3.6. Implementation of FCM model to the study

The connection or adjacency matrix M is obtained by taking risk factors $(P,\ U, E, I, A,$ $SI, FB, MI,\ NGO, Pop, GA,\ CH, RS,\ C, H)$as the rows head and columns head respectively, assigning values as 1, if there is any relation between nodes and 0, if there is no relation between nodes. Here we consider three cases to study the problem, for case-1, the activated concepts are CJSI, A, MI, H where as the concepts involved for case-2, are E, MI,NGO, I,H and activated concepts for case-3 are CJSI, A, FB, I, E, SI, H.

The connection matrix for Case-1

	CJSI	A	MI	RS	H
CJSI	0	0	0	0	1
A	0	0	0	0	0
MI	0	0	0	0	1
RS	0	0	0	0	0
H	1	0	1	0	0

Following our Directed graph of homelessness, consider: the concept, CJSI, is active and all other nodes are in inactive mode for some individual. Therefore, CJSI=1. This is expressed by a vector C_1 = (1,0,0,0,0). According to the Algorithm in Induced Fuzzy Cognitive Map, the processing is listed in Table 2.

C_1M	=	(0 0 0 0 1)			=	C_2	
C_2M	=	(1 0 1 0 0)			=	C_3	
C_3M	=	(0 0 0 0 2)	$\hookrightarrow$	(0 0 0 0 1)	=	C_4	$\Leftrightarrow C_2$

Table 2: FCM processing when CJSI=1

C_1M	=	(0 0 0 0 0)			=	C_2	
C_2M	=	(0 0 0 0 0)			=	C_3	
C_3M	=	(0 0 0 0 0)			=	C_4	$\Leftrightarrow C_2$

Table 3: FCM processing when A=1

C_1M	=	(0 0 0 0 1)			=	C_2	
C_2M	=	(1 0 1 0 0)			=	C_3	
C_3M	=	(0 0 0 0 2)	$\hookrightarrow$	(0 0 0 0 1)	=	C_4	$\Leftrightarrow C_2$

Table 4: FCM processing when MI=1

C_1M	=	(0 0 0 0 0)			=	C_2	
C_2M	=	(0 0 0 0 0)			=	C_3	
C_3M	=	(0 0 0 0 0)			=	C_4	$\Leftrightarrow C_2$

Table 5: FCM processing when RS=1

The connection matrix for Case-2

	E	MI	NGO	I	H
E	0	0	0	1	1
MI	0	0	0	0	1
NGO	0	0	0	0	1
I	1	0	0	0	1
H	1	1	1	1	0

C_1M	=	(0 0 0 1 1)			=	C_2	
C_2M	=	(2 1 1 1 1)	↪	(1 1 1 1 1)	=	C_3	
C_3M	=	(2 1 1 2 4)	↪	(1 1 1 1 1)	=	C_4	$\Leftrightarrow C_2$

Table 6: FCM processing when E=1

C_1M	=	(0 0 0 0 1)			=	C_2	
C_2M	=	(1 1 1 1 0)			=	C_3	
C_3M	=	(1 0 0 1 4)	↪	(1 0 0 1 1)	=	C_4	
C_4M	=	(2 1 1 2 2)	↪	(1 1 1 1 1)	=	C_5	
C_5M	=	(2 1 1 2 4)	↪	(1 1 1 1 1)	=	C_6	$\Leftrightarrow C_5$

Table 7: FCM processing when MI=1

C_1M	=	(0 0 0 0 1)			=	C_2	
C_2M	=	(1 1 1 1 0)			=	C_3	
C_3M	=	(1 0 0 1 4)	↪	(1 0 0 1 1)	=	C_4	
C_4M	=	(2 1 1 2 2)	↪	(1 1 1 1 1)	=	C_5	
C_5M	=	(2 1 1 2 4)	↪	(1 1 1 1 1)	=	C_6	$\Leftrightarrow C_5$

Table 8: FCM processing when NGO =1

C_1M	=	(1 0 0 0 1)			=	C_2	
C_2M	=	(1 1 1 2 1)	↪	(1 1 1 1 1)	=	C_3	
C_3M	=	(2 1 1 2 4)	↪	(1 1 1 1 1)	=	C_4	$\Leftrightarrow C_2$

Table 9: FCM processing when I =1

The connection matrix for Case-3

	CJSI	A	FB	I	E	SI	H
CJSI	0	0	0	0	0	0	1
A	0	0	1	0	1	0	0
FB	0	1	0	0	0	1	0
I	0	0	0	0	1	0	1
E	0	0	0	1	0	0	1
SI	0	0	1	0	0	0	1
H	1	0	0	1	1	1	0

Table 10: FCM processing when E =1

C_1M	=	(0 0 0 1 0 0 1)			=	C_2	
C_2M	=	(1 0 0 1 1 1 1)			=	C_3	
C_3M	=	(1 0 1 2 2 1 4)	↪	(1 0 1 1 1 1 1)	=	C_4	
C_4M	=	(1 1 1 2 2 2 4)	↪	(1 1 1 1 1 1 1)	=	C_5	
C_5M	=	(1 1 2 2 2 2 4)	↪	(1 1 1 1 1 1 1)	=	C_6	$\Leftrightarrow C_5$

Table 11: FCM processing when CJSI =1

4. Measure of centrality

There are many measurements for analyzing an FCM, but here we focus on Measure of centrality. In this subsection, we describe the results of the analysis based on two types of centrality: degree centrality and closeness centrality. Degree centrality of each node/concept, in a given weighted and directed graph, is defined as the sum of the absolute values of the weights of the outgoing and incoming edges. It indicates how strongly a concept node in a FCM affects other concept nodes of the graph. Closeness centrality of a node is the inverse of the sum of the lengths of the shortest paths between that node and all other nodes. It indicates how quickly a concept node affects other nodes of the FCM.

Concepts	**Degree centrality**	**Closeness centrality**
CJSI	0.13	0.48
NGO	0.07	0.43
CH	0.07	0.43
Pop	0.07	0.43
I	0.2	0.48
GA	0.27	0.5
RS	0.07	0.34
U	0.13	0.38
E	0.27	0.52
P	0.2	0.52
MI	0.13	0.48
SI	0.2	0.5
FB	0.13	0.38

C	0.2	0.41
A	0.13	0.33

Table 14: Degree centrality and closeness centrality of every concept

C_1M	=	(0 0 0 0 0 0 1)			=	C_2	
C_2M	=	(1 0 0 1 1 1 0)			=	C_3	
C_3M	=	(0 0 1 1 1 0 4)	$\hookrightarrow$	(0 0 1 1 1 0 1)	=	C_4	
C_4M	=	(1 1 0 2 2 2 2)	$\hookrightarrow$	(1 1 0 1 1 1 1)	=	C_5	
C_5M	=	(1 0 2 2 2 1 4)	$\hookrightarrow$	(1 0 1 1 1 1 1)	=	C_6	
C_6M	=	(1 1 1 2 2 2 4)	$\hookrightarrow$	(1 1 1 1 1 1 1)	=	C_7	
C_7M	=	(1 1 2 2 2 2 4)	$\hookrightarrow$	(1 1 1 1 1 1 1)	=	C_8	$\Leftrightarrow C_7$

Table 11: FCM processing when CJSI =1

C_1M	=	(0 0 1 0 0 0 1)			=	C_2	
C_2M	=	(1 1 0 1 1 1 0)			=	C_3	
C_3M	=	(0 0 2 1 1 0 4)	$\hookrightarrow$	(0 0 1 1 1 0 1)	=	C_4	
C_4M	=	(1 1 0 2 2 2 2)	$\hookrightarrow$	(1 1 0 1 1 1 1)	=	C_5	
C_5M	=	(1 0 2 2 2 1 4)	$\hookrightarrow$	(1 0 1 1 1 1 1)	=	C_6	
C_6M	=	(1 1 1 2 2 2 4)	$\hookrightarrow$	(1 1 1 1 1 1 1)	=	C_7	
C_7M	=	(1 1 2 2 2 2 4)	$\hookrightarrow$	(1 1 1 1 1 1 1)	=	C_8	$\Leftrightarrow C_7$

Table 12: FCM processing when SI =1

C_1M	=	(0 0 1 0 0 0 0)			=	C_2	
C_2M	=	(0 1 0 0 0 1 0)			=	C_3	
C_3M	=	(0 0 2 0 0 0 1)	$\hookrightarrow$	(0 0 1 0 0 0 1)	=	C_4	
C_4M	=	(1 1 0 1 1 2 0)	$\hookrightarrow$	(1 1 0 1 1 1 0)	=	C_5	
C_5M	=	(0 0 2 1 1 0 4)	$\hookrightarrow$	(0 0 1 1 1 0 1)	=	C_6	
C_6M	=	(1 1 0 2 2 2 2)	$\hookrightarrow$	(1 1 0 1 1 1 1)	=	C_7	
C_7M	=	(1 0 2 2 2 1 4)	$\hookrightarrow$	(1 0 1 1 1 1 1)	=	C_8	
C_8M	=	(1 1 1 2 2 2 4)	$\hookrightarrow$	(1 1 1 1 1 1 1)	=	C_9	
C_9M	=	(1 1 2 2 2 2 4)	$\hookrightarrow$	(1 1 1 1 1 1 1)	=	C_{10}	$\Leftrightarrow C_9$

Table 13: FCM processing when A =1

5. Conclusion

After analyzing the results from the above FCM processing tables and measure of centrality table we may conclude that people of Bangladesh regarding homelessness are badly affected by various social factors such as Government Assistance, Education, Poverty, Income, Mental Illness etc. As shown in table 14, Education and Government Assistance has the greatest degree centrality while NGO, Population, Cost of Housing and Rental Subsidy has the least. This means that Education and Government gives and receives the greatest direct influence on all other concepts, where as NGO, Population, Cost of Housing and Rental Subsidy gives and receives the least. Similarly, closeness centrality identify that Education and Poverty exerts the greatest force on the map, in reference to closeness centrality with changes in Education and Poverty resulting in the most prominent changes in the other concepts. Likewise, changes in Addiction would result in the least amount of change in all other concepts. These results are consistent with the results of the overall experiment.

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