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New Merged Fuzzy Cognitive Maps

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Abstract

In this paper authors introduce a new type of Fuzzy Cognitive Maps model called the merged Fuzzy Cognitive Maps model.This new concept is based on the merged graphs and merged matrices.

Keywords: Fuzzy Cognitive Maps (FCMs) model, merged graphs, merged matrices, Merged Fuzzy Cognitive Maps (MFCMs).

Introduction

In this paper we introduce the notion of Merged Fuzzy Cognitive Maps (MFCMs). Merged FCMs are built using the concept of merged graphs and the related merged matrices. Specially merged linked FCMs are constructed using the concept of specially merged linked graphs and specially linked merged matrices. These models can be used to analyse social problem engineering problem medical problem and so on.

Definition 1: Let $C = \{C_1, \ldots, C_n\}$ be the n nodes associated with a real world problem. Suppose t experts want to work with this problem using FCMs but only using some selected nodes from the set of nodes C.

Let the directed graphs given by the t experts be $G_1, G_2, \ldots, G_t$ such that the vertex set of the graph G_i with G_j is non empty for $i \neq j$; $G_i \cap G_j \neq \phi$; $1 \leq i, j \leq t$. Then we can merge some graphs say k of them, $k \leq t$ from $G_1, \ldots, G_t$ so that the vertices of all these graphs give all the nodes of the set C.

Let G be the merged graph and the FCMs associated with G will be known as the Merged Fuzzy Cognitive Maps (MFCMs) and the connection matrix associated with G will be known as the merged connection matrix of the MFCMs or the merged dynamical system of the FCMs.

We will first illustrate this situation by an example.

Example 1: Let us suppose we have $C = \{C_1, C_2, C_3, \ldots, C_{12}\}$ to be the set of nodes/ attributes associated with a problem. Let five experts work with the problem using FCMs and the nodes from the set C.

Suppose the first expert wants to work with the set of nodes given by X_1 where $X_1 = \{C_1, C_2, C_3, C_4, C_8\} \subseteq C$ and the second expert wishes to work with the set of nodes given by X_2, where $X_2 = \{C_3, C_7, C_5, C_{12}\} \subseteq C$.

The third expert works with the set of nodes given by the subset X_3, where

$$X_3 = \{C_1, C_7, C_{10}, C_{11}\} \subseteq C.$$

Let the forth expert work with the nodes C_6, C_9, C_1, C_{10}, C_{12} given by the set

$$X_4 = \{C_6, C_9, C_1, C_{10}, C_{12}\} \subseteq C.$$

The fifth expert works with $X_5 = \{C_6, C_5, C_{10}, C_2, C_9, C_7\} \subseteq C$. Now we can get the merged FCMs in two ways. Taking the nodes $X_1 \cup X_2 \cup X_3 \cup X_4$ so that we get the merged graph G of the graphs G_1, G_2, G_3 and G_4 or $X_1 \cup X_2 \cup X_3 \cup X_5$ that is we get the merged graph G' of the graphs G_1, G_2, G_3 and G_5.

So we get two integrated merged FCMs model to work with. Let us consider the directed graphs given by the five experts.

Let G_1 be the directed graph given in Figure 1 by the first expert using the set of attributes X_1.

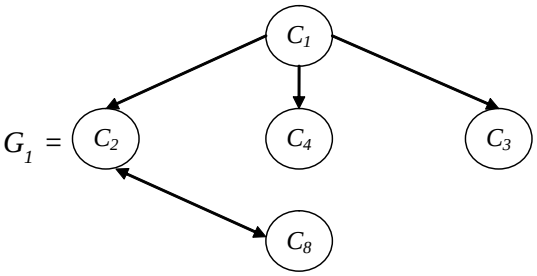

Figure 1

Let M_1 be the matrix associated with the graph G_1.

$$M_1 = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_8 \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & C_4 & C_8 \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \end{bmatrix} \end{array}.$$

Let G_2 be the directed graph given by the second expert using the attributes $X_2 = \{C_3, C_7, C_5, C_{12}\}$ given in Figure 2.

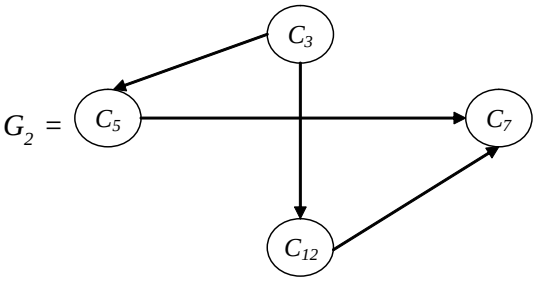

Figure 2

Let M_2 be the matrix associated with the graph G_2.

$$M_2 = \begin{array}{c} \\ C_3 \\ C_5 \\ C_7 \\ C_{12} \end{array} \begin{array}{c} \begin{array}{cccc} C_3 & C_5 & C_7 & C_{12} \end{array} \\ \begin{bmatrix} 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \end{array}.$$

Let G_3 be the directed graph given in Figure 3 given by the third expert using the nodes $X_3 = \{C_1, C_7, C_{10}, C_{11}\}$;

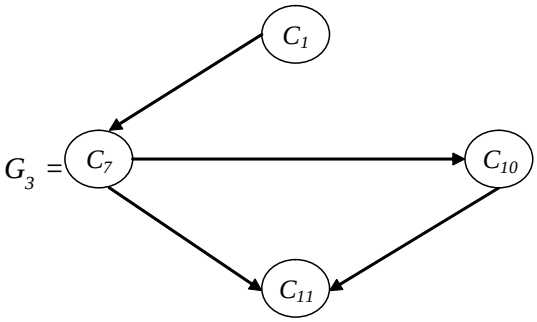

Figure 3

Let M_3 be the matrix associated with the graph G_3.

$$M_3 = \begin{array}{c} \\ C_1 \\ C_7 \\ C_{10} \\ C_{11} \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_7 & C_{10} & C_{11} \end{array} \\ \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \end{array}.$$

Let G_4 be the directed graph provided by the fourth expert using the set of nodes $X_4 = \{C_6, C_9, C_1, C_{12}, C_{10}\}$ given in Figure 4.

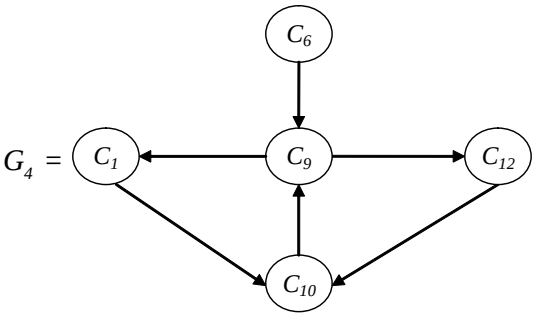

Figure 4

Let M_4 be the matrix associated with the graph G_4.

$$M_4 = \begin{array}{c} \\ C_1 \\ C_6 \\ C_9 \\ C_{10} \\ C_{12} \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_6 & C_9 & C_{10} & C_{12} \end{array} \\ \begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \end{array}.$$

Using $X_5 = \{C_6, C_5, C_{10}, C_2, C_9, C_7\}$, let G_5 be the directed associated with the fifth expert given in Figure 5.

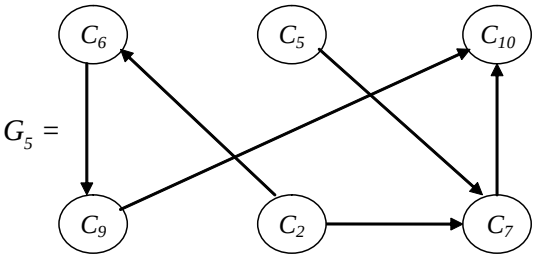

Figure 5

Let M_5 be the matrix associated with the graph G_5.

$$M_5 = \begin{array}{c} \\ C_2 \\ C_5 \\ C_6 \\ C_7 \\ C_9 \\ C_{10} \end{array} \begin{array}{c} \begin{array}{cccccc} C_2 & C_5 & C_6 & C_7 & C_9 & C_{10} \end{array} \\ \begin{bmatrix} 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array}.$$

Let $M_1, M_2, \ldots, M_5$ be the matrices associated with the graphs $G_1, G_2, \ldots, G_5$ respectively. Let the specially linked merged matrix of the matrices be M which is also the specially linked merged connection matrix M of the specially linked merged graph G given in Figure 6.

Now to get the integrated merged FCMs we have to merge the graphs G_1,G_2, G_3 and G_4 or G_1, G_2, G_3 and G_5. So we get in total using merged FCMs two integrated merged FCMs using all the 12 attributes. The specially linked merged graph G of the experts 1 to 4 is given in Figure 6.

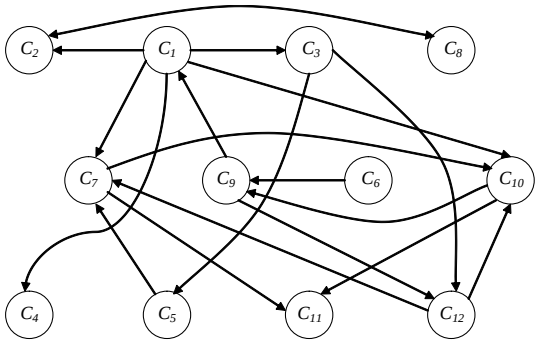

Figure 6

Using this specially linked merged connection matrices M_1, M_2, M_3 and M_4 of the graphs G_1, G_2, G_3 and G_4 respectively we can study the integrated specially linked merged dynamical system of the integrated specially[2-5] linked merged FCMs.

$$M = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \\ C_{10} \\ C_{11} \\ C_{12} \end{array} \begin{array}{c} \begin{array}{cccccccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 & C_{10} & C_{11} & C_{12} \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array}.$$

Now using the experts 1, 2, 3, and 5 we get the merged graph G' of the four directed graphs of the FCM given in Figure 7.

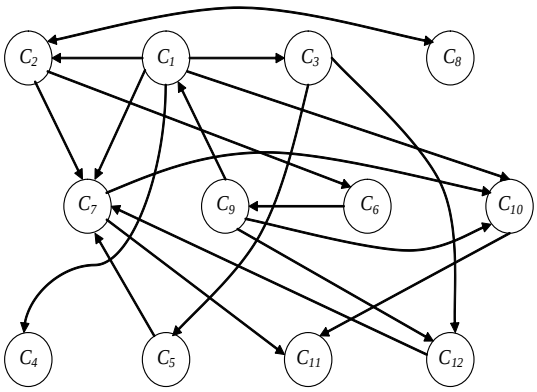

Figure 7

Let the specially linked merged connection matrix of the matrices M_1, M_2, M_3 and M_5 of the specially linked merged graph G' of Figure 7 be M' which is as follows:

$$M' = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ C_7 \\ C_8 \\ C_9 \\ C_{10} \\ C_{11} \\ C_{12} \end{array} \begin{array}{c} \begin{array}{cccccccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & C_7 & C_8 & C_9 & C_{10} & C_{11} & C_{12} \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array}.$$

Thus we can find the merged connection matrix M' of the FCM and study the problem. The advantages of using this new[6-8] merged FCMs models are;

1. Experts can choose any number of attributes from the given set of attributes so that they can be free to do work with the problem with their choice.
2. When the number of attributes is a small number; working is easy and apt.
3. While getting merged model we combining all the experts opinion so no expert is left out, everyone is given the same degree of importance.
4. By combining them differently using different sets of experts we get several merged FCMs for the same problem.
5. The values in the connection merged integrated matrices need not be thresholded for they take only values from the set {–1, 1, 0}.

Now we proceed onto define and describe the Specially Merged Linked Fuzzy Cognitive Maps (SMLFCMs) model.

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