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Application of Graph Theory in Fuzzy Cognitive Mapping: Analysing organic agriculture

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Abstract

Fuzzy cognitive maps (FCM) are cognition fuzzy influence graphs, which are based on fuzzy logic. It plays a vital role in decision making, data analysis and socio-economic problem solving etc., In this paper, FCM is used to analyse the organic agricultural patterns so as to understand the attributes that affect the agricultural practices.

Key words: FCM, State vector, Hidden pattern, Thresholding, Updating.

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INTRODUCTION

FCM was introduced by Bart Kosko in the year 1986. It can be understood as a graphical representation of the knowledge of a given system. Cognitive mapping is based on graph theory. Hence Fuzzy cognitive mapping is a combination of fuzzy logic and cognitive mapping(Khan, M.S. and Khor, S.W. 2004). It consists of factors (concepts / nodes) which represent the important elements of mapped system. The directed lines labeled with values show the strength of the causal conditions between factors. It is a model of system structure. It has a major role to play when the data concerned is unsupervised (Vasantha Kandasamy,W.B.2003.). This method is very simple and effective one as it can analyse the data by directed graphs and connection matrices.

In this paper, agricultural attributes were analysed with the help of FCM. Since, farming practices vary from place to place and time to time, due to changing nature of agriculture, FCM becomes handy to apply the data and analyse them easily.

Description of FCM

FCM are signed directed graph with feedback. The directed edge e_{ij} from causal concept c_i to concept c_j measures how much c_i causes c_j.In FCM,c_1,c_2, ... , c_n are Nodes.The edge weights of c_{ij} are taken from set (1,0,-1).

- The edge weight 1 will be given if concept c_i and c_j are direct. That is, If c_i increase or decrease,c_j also increases or decreases.
- -1 denotes that c_i and c_j are opposites. That is, If c_i increase c_j decreases and if c_i decreases then c_j increases.
- If there is no causality denote it by 0.

The adjacency matrix E is defined by E = (e_{ij}), where e_{ij} is the weight of directed edge $c_i c_j$. Clearly, E is a n× n matrix, here the diagonal entries are zero, since the weight of the edge $c_i c_j$ does not exist.

Preliminaries

Definition 1

Let A=(a_1,a_2....a_n) where a_i=(0,1) is called the state vector in which

a_i=0 if a_i is OFF

a_i=1 if a_i is ON for i=1,2....n

Definition 2

A FCMis said to be cyclic if it poses a directed cycle.

Definition 3

A FCM with cycles is said to have a feed back.

Definition 4

A FCM is called a Dynamical system, if the causal relation flows through a cycle in a revolutionary way.

Definition 5

The equilibrium state of a dynamical system is a unique state vector, then it is called a Fixed point.

Definition 6

The equilibrium state for the dynamical system is called the Hidden pattern.

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Working Procedure

Let $A=(a_1,a_2.....a_n)$ be a state vector which is passed to the dynamical system E.Then$AE = (a_{11},a_{12},.....,a_{1n})$, and then AEis Thresholding and Updating (denoted by →).

Updating

The state of nodes which is ON in the initial state vector must remain ON till the hidden pattern is found.

Thresholding

If $a_i \leq 0$,replace it by 0,If $a_i > 0$,replace it by 1.

Repeat this process until a fixed point is arrived.

Description of the problem

Agriculture is the cultivation of land and breeding of animals and plants to provide food and other products to sustain and enhance life.Without agriculture there could be no civilized life.It is the first and foremost one for every organisation to survive.After analysing the attributes in agriculture, the following were taken as major affecting factors.

S_1 :: High Input cost
S_2 :: Shortage of Bio-mass
S_3 :: Livestock production
S_4 :: Optimum usage of water
S_5 :: Higher profitability
S_6 :: Marketing probability of output
S_7 :: Low Yields

The fuzzy cognitive mapping(Figure 1) for the above attributes is

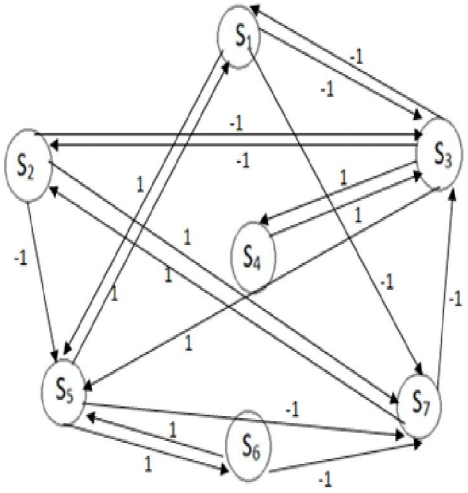

Fig.1. Directed weighted graph of the FCM

The adjacency matrix for the above mapping E is given by

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
S_1	0	0	-1	0	1	0	-1
S_2	0	0	-1	0	-1	0	1
S_3	-1	-1	0	1	1	0	0
S_4	0	0	1	0	0	0	0
S_5	1	0	0	0	0	1	-1
S_6	0	0	0	0	1	0	-1
S_7	0	1	-1	0	0	0	0

We now analyse the effect of state vector and determine the hidden pattern.

Suppose if S_1 is ON (ie.)High input cost is ON,

A_1= (1 0 0 0 0 0 0), then

A_1E=(0 0 -1 0 1 0 -1) ⟶ (1 0 0 0 1 0 0)=A_1^I

A_1^IE = (1 0-1 0 1 1 -2)⟶ (1 0 0 0 1 1 0)=A_1^{II}

$A_1^{II}E$ =(1 0 0 0 2 1 -3)⟶ (1 0 0 0 1 1 0)=A_1^{III}

Hence, $A_1^{II} = A_1^{III}$

Therefore, if the high input cost is ON, then it makes the higher profitability and marketing probability of outputare ON.

Next, if shortage of biomass ie.,S_2 is ON, then,

A_2 = (0 1 0 0 0 0 0),

A_2E = (0 0 -1 0 -1 0 1) ⟶ (0 1 0 0 0 0 1) =A_2^I

A_2^IE = (0 1 -2 0 -1 0 1)⟶ (0 1 0 0 0 0 1) =A_2^{II}

Hence, $A_2^I = A_2^{II}$

Thus, if the shortage of biomass is ON, then low yields is ON.

Let A_3 = (0 0 1 0 0 0 0)

A_3E=(-1 -1 0 1 1 0 0) ⟶ (0 0 1 1 1 0 0)=A_3^I

A_3^IE=(0 -1 1 1 1 1 -1) ⟶ (0 0 1 1 1 1 0)=A_3^{II}

$A_3^{II}E$=(0 -1 1 1 2 1 -2)⟶ (0 0 1 1 1 1 0)=A_3^{III}

Hence, $A_3^{II} = A_3^{III}$

Therefore, if the livestock reduction is ON, then, the optimum usage of water, higher profitability and marketing probability of output are all ON.

Let A_4= (0 0 0 1 0 0 0)

A_4E = (0 0 1 0 0 0 0) ⟶ (0 0 1 1 0 0 0) =A_4^I

A_4^IE = (-1 -1 1 1 1 0 0)⟶ (0 0 1 1 1 0 0)=A_4^{II}

$A_4^{II}E$ = (0-1 1 1 1 1 -1) ⟶ (0 0 1 1 1 1 0)=A_4^{III}

$A_4^{III}E$ = (0-1 1 1 2 1 -2)⟶ (0 0 1 1 1 1 0)=A_4^{IV}

Hence, $A_4^{III} = A_4^{VI}$

Therefore, if optimum usage of wateris ON,then livestock production, higher profitability and marketing probability of output are ON.

Let A_5= (0 0 0 0 1 0 0)
A_5E = (1 0 0 0 0 -1 0) ⟶ (1 0 0 0 1 1 0) = A_5^I
A_5^IE = (1 0 -1 0 2 1 -3) ⟶ (1 0 0 0 1 1 0) = A_5^{II}
Hence, $A_5^{II} = A_5^{III}$
Therefore, if higher profitabilityis ON,then high input costand marketing probability of output are ON.

Let A_6 = (0 0 0 0 0 1 0)
A_6E = (0 0 0 0 1 0 -1) ⟶ (0 0 0 0 1 1 0) = A_6^I
A_6^IE = (1 0 0 0 1 1 -2) ⟶ (1 0 0 0 1 1 0) = A_6^{II}
$A_6^{II}E$ = (1 0 -1 0 2 1 -3) ⟶ (1 0 0 0 1 1 0) = A_6^{III}
Hence, A_6^{II}= A_6^{III}
Therefore, if marketing probability of output is ON,then high input cost and higher profitability yare ON

Let A_7 = (0 0 0 0 0 0 1)
A_7E = (0 1 -1 0 0 0 0) ⟶ (0 1 0 0 0 0 1) = A_7^I
A_7^IE = (0 1 -2 0 -1 0 1) ⟶ (0 1 0 0 0 0 1) = A_7^{II}
Hence, A_7^I= A_7^{II}
Therefore, if low yieldsis ON,then shortage of biomass is ON.

Inference

1.The high input cost is ON, then it makes the higher profitabilityand marketing probability of output are ON. Hence it creates a positive approach in agriculture.

2.The shortage of biomass is ONthen it leads to low yields is ON.To prevent this, the farmersincreasedthe cattle production.

3. If the livestock production is ON, then, the optimum (max/min) usage of water usage of water, higher profitability and marketing probability of output are all ON. So the farmers should concentrate on the animal husbandry.

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