Using Fuzzy Cognitive Maps for E-Commerce Strategic Planning

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Abstract. In this paper we propose the use of Fuzzy Cognitive Map (FCM), a well-established Artificial Intelligence technique that incorporates ideas from Artificial Neural Networks and Fuzzy Logic, for E-Commerce strategic planning. FCMs create models as collections of concepts and the various causal relations that exist between these concepts. The strategic planning capabilities of the FCM structure are examined and presented using a model concerning the e-commerce section of an e-business company. The model is examined dynamically through simulations, in order to simulate scenarios proposed by company's managers. Strategic Planning is made by viewing dynamically the consequences of the scenario's actions. Conclusions are drawn for the use of FCM for e-commerce strategic planning.

1 Introduction to Fuzzy Cognitive Maps

Fuzzy Cognitive Maps have been introduced by Kosko [1, 2] based on Axelord's work on Cognitive Maps [3] and are considered a combination of fuzzy logic and artificial neural networks. FCMs create models as collections of concepts and the various causal relations that exist between these concepts [4]. The concepts are represented by nodes and the causal relationships by directed arcs between the nodes. Each arc is accompanied by a weight that defines the type of causal relation between the two nodes. The sign of the weight determines the positive or negative causal relation between the two concepts-nodes. An example of FCM concerning public health is given in figure 1.

Two nodes/concepts are connected either by a direct arc or by a path. An arc between two concepts indicates a direct causal relation while a path between two nodes of the digraph indicates an indirect causal relation. The sign of the indirect causal relationship is positive if the path has an even number of negative direct causal relationships, while it is negative if the path has an odd number of negative direct causal relationships.

The total effect that a concept has to another is given based on all indirect causal relationships that exist from the one concept to the other and also by the direct causal relation that might exist. The following rules are used to evaluate the total effect:

- The total effect is positive if all the indirect causal relationships that exist from the one concept to the other are positive and also the direct causal relationship that might exist is also positive.

- The total effect is negative if all the indirect causal relationships that exist from the one concept to the other are negative and also the direct causal relationship that might exist is also negative.
- The total effect is unknown if all the indirect causal relationships that exist from the one concept to the other are positive and the direct causal relationship are not of the same sign.

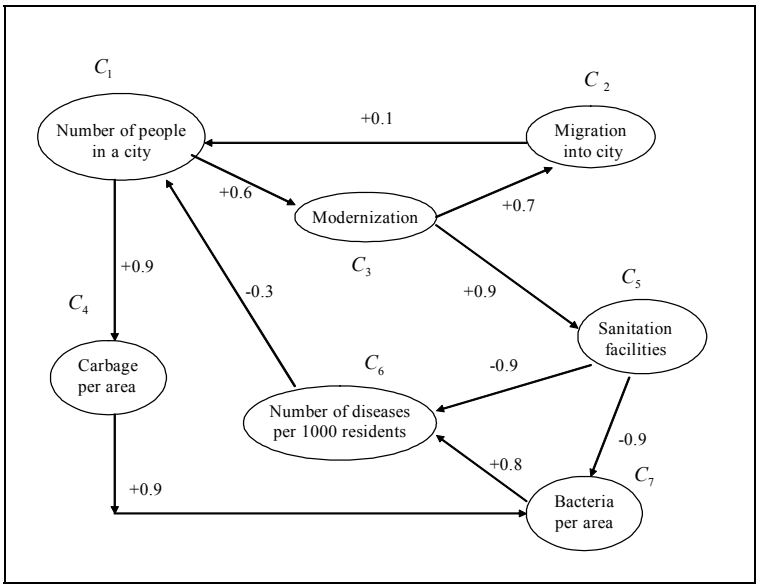

Figure 1: An FCM concerning public health [5]

The main areas where FCMs are used are: a) Decision Making, b) Forecasting, c) Explanation (of actions already made) and d) Strategic Planning. A great number of FCMs have been developed concerning the business industry and financial activities. Table I gives some such references found in bibliography.

Cognitive Map topic	Reference
Japan's and USA's industry	[6]
The strategy of NeXT computer Company	[7]
The strategy of Sony Company	[7]
USA's economy	[9]
The introduction of a new drink in the market	[9]
Measuring the efficiency of a company's departments	[10]
The development phases of a company	[11]
The sales of a company	[12]
The management of a company	[13, 14]
The bureaucracy in companies	[11]

Table 1

2 Certainty Neuron Fuzzy Cognitive Maps

Although in FCMs the degree of the causal relationships could be represented by a number in the interval [-1,1], each concept could be either activated or not activated, in a strict binary manner. In 1997, Certainty Neuron Fuzzy Cognitive Maps (CNFCMs) were introduced [4] to overcome this limitation. CNFCMs provide additional fuzzification to FCMs by allowing each concept's activation to be activated just to a degree. In this way the activation level of each concept can be any value of the interval [-1,1] and not only one of the two levels –1 and 1. The aggregation of the influences that each concept receives from other concepts is handled by function $f_M()$ that was used in MYCIN Expert System [15, 16] for certainty factors' handling. The dynamical behaviour and the characteristics of this function are studied in [17]. Certainty Neurons are defined as artificial neurons that use this function as their threshold function [18]. Using such neurons, the updating function of CNFCMs as a dynamical evolving system is the following:

$$A_i^{t+1} = f_M\,(A_i^t, S_i^t) - d_i\,A_i^t \tag{1}$$

where,

A_i^{t+1} is the activation level of concept C_i at time step t+1,

$S_i^t = \sum_j w_{ji} A_j^t$ is the sum of the weight influences that concept C_i receives at time step *t* from all other concepts,

d_i is a decay factor and

$$f(A_i^t, S_i^t) = \begin{cases} A_i^t + S_i^t(1 - A_i^t) = A_i^t + S_i^t - S_i^t A_i^t & \text{if } A_i^t \geq 0, S_i^t \geq 0 \\ A_i^t + S_i^t(1 + A_i^t) = A_i^t + S_i^t + S_i^t A_i^t & \text{if } A_i^t < 0, S_i^t < 0 \quad |A_i^t|, |S_i^t| \leq 1 \\ (A_i^t + S_i^t) \big/ \left(1 - \min(|A_i^t|, |S_i^t|)\right) & \text{if } A_i^t S_i^t < 0 \end{cases} \tag{2}$$

is the function that was used for the aggregation of certainty factors to the MYCIN expert system.

3 E-Commerce Fuzzy Cognitive Map

To examine the strategic planning capabilities of the FCM structure, we will use the FCM model of figure 2. The FCM model of figure 2 is a modified version of the model presented in [19] and concerns an imaginary E-business company.

According to the FCM model of the e-business company of Figure 2, the concepts that were identified as playing important role in the strategic planning process of the e-business company are the following:

C1: E-Business Profits	C5: Staff Recruitments
C2: E-Business Sales	C6: Impact from International E-Business Competition
C3: Prices Cutoffs	
C4: Customers Satisfaction	C7: Better E-Commerce Services

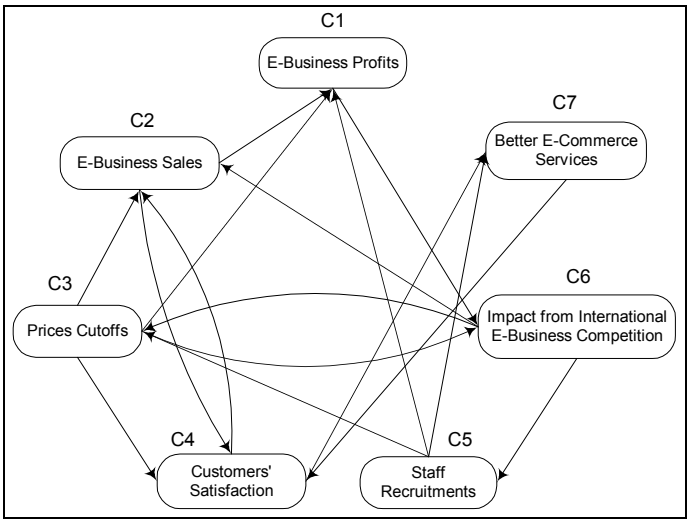

Figure 2. FCM model of an e-business company

The weights of the causal relationships that according to the company's managers and experts exist in the model and construct the weight matrix of the model, are presented in Appendix A.

Letting initially all concepts of the FCM system to free interact with each other (scenario #1), the dynamical behaviour of figure 3 is exhibited. The system gets into a periodic - limit cycle - dynamical behaviour, with activation of all concepts to increase and decrease in turn. In terms of economy, this means that the concepts are in struggle with each other, all concepts trying to get equilibrium but none of them to reach it. Periodically increase and decrease of these concepts are predicted.

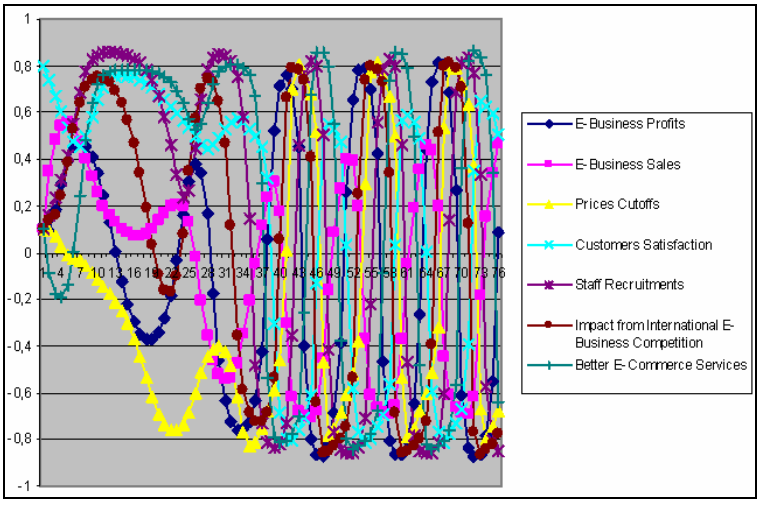

Figure 3. Simulation of e-commerce company model for scenario #1 - (limit cycle behaviour)

In the above scenario, according to the model, "Staff Recruitment" has a medium negative impact to concept "Prices Cutoffs"(weight w_{53}=-0.4), meaning that staff recruitment will negatively affect prices cutoffs. This is because the company will not easily be able to have prices cutoffs if it acquires new staff. This could be partially caused by the fact that e-commerce technical staff requires high salaries, no giving the opportunity to the company to have high price cutoffs.

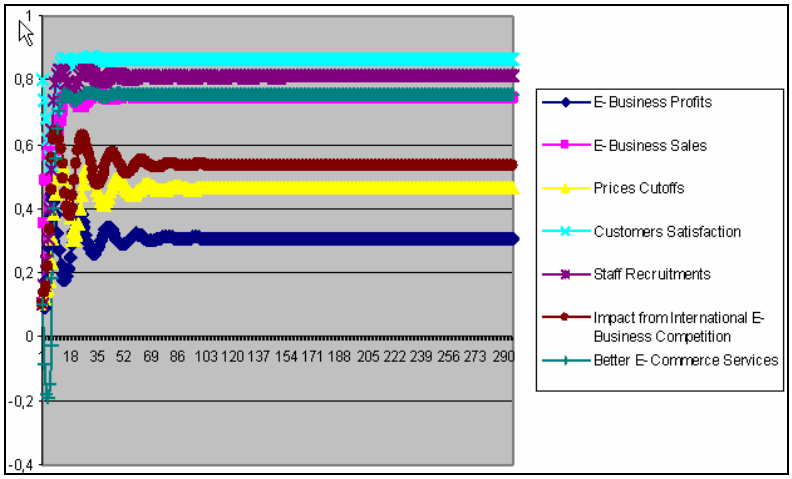

Figure 4. Simulation of e-commerce company model for scenario #2, (w_{53}=-0.2, equilibrium)

Introducing a different scenario to the FCM system, weight w_{53} is be set from -0.4 to -0.2 lowering the negative affect of "Staff Recruitment" to concept "Prices Cutoffs" (scenario #2). This can be done perhaps by of a changing company's structure (use cheaper technical staff from all over the world, using teleworking) or increase of e-business technical staff availability. Using simulations to get the impact from this change (that can be an act of strategic planning), the FCM model exhibited the dynamical behaviour of figure 4. The system after a short transition phase, reaches an equilibrium point. The activation lever of each concept of the model at equilibrium is that of Table 2.

E-Business Profits	E-Business Sales	Prices Cutoffs	Customers Satisfaction	Staff Recruitments	Impact from International E-Business Competition	Better E-Commerce Services
0,307	0,745	0,463	0,865	0,810	0,534	0,755

Table 2

The equilibrium can be justified as follows: The strong impact (0.534) from international e-business competition, led the e-commerce company to highly increase its staff ("Staff Recruitments"=0.810) in order to provide better e-commerce services (0.755) to its customers. In parallel, the company managed to have prices cutoffs (0.463) to e-commerce products, which together with better services caused a very big increase to "Customer Satisfaction" (0.865). This led to an increase to e-business

sales (0.745) that caused an increase to e-business profits (0.307) although additional expenses exist due of the new staff.

According to the model, weight $w_{76} = 0$, meaning that there is no direct influence from concept "Better E-Commerce Services" to concept "Impact from International E-Business Competition". Next scenario (scenario #3) applies when companies experts claims that such a small negative influence exists, e.g. $w_{76} = -0.3$. Introducing this change to the FCM model, the system reaches once again equilibrium, but now to a different point. The activation levels of all concepts at this new equilibrium point appear to Table 3. The transition phase to this equilibrium is shown in figure 5.

E-Business Profits	E-Business Sales	Prices Cutoffs	Customers Satisfaction	Staff Recruitments	Impact from International E-Business Competition	Better E-Commerce Services
0,459	0,711	0,245	0,845	0,778	0,438	0,744

Table 3

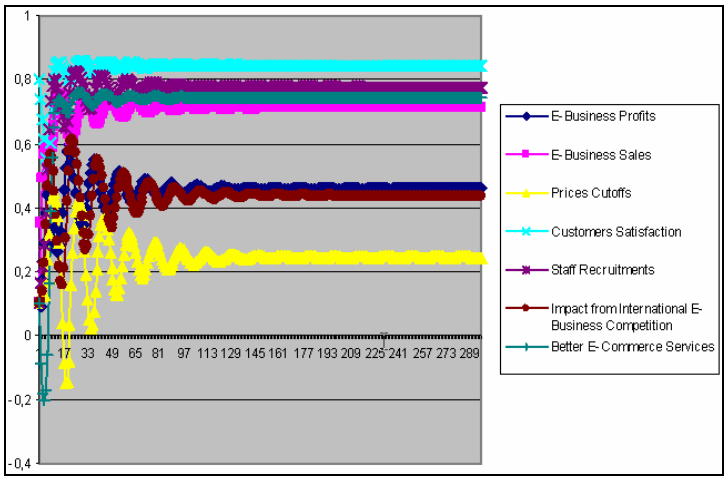

Figure 5. Simulation of e-commerce company model for scenario #3, ($w_{76} = -0.3$, equilibrium)

Comparing this equilibrium point with that of scenario #2 we see that the impact from International e-business competition is now lower, leading to less staff recruitments. Customers Satisfaction remain high (0,845) but prices cutoffs are now lower (0.245 compared to 0.463 of scenario #2). This led to have almost the same e-business sales, but higher e-business profits.

To check once again the strategic planning and predicting capabilities of FCM method, let's change the way that the "impact of international e-business competition" affect the e-company's price cutoffs. To scenarios #1,#2 and #3 weight w_{63} was set to 0.4. This was part of company's policy according which the reaction to strong foreign competition is to cut prices and get new staff to provide better e-commerce services. Lets imagine a new case (scenario #4) where prices can not get high cutoffs.

In this case weight w_{63} is changed from 0.4 to 0.2. Simulating this scenario and letting all model's concepts free to interact, we get the dynamical behaviour of figure 6. The system after a short transition phase gets into a limit cycle behaviour with all concepts periodically to increase and decrease. No clear conclusions can be drawn for the outcome of the small price cutoffs of scenario #4, in contrary to the clear conclusions that were found for scenario #3 where price cutoffs were higher.

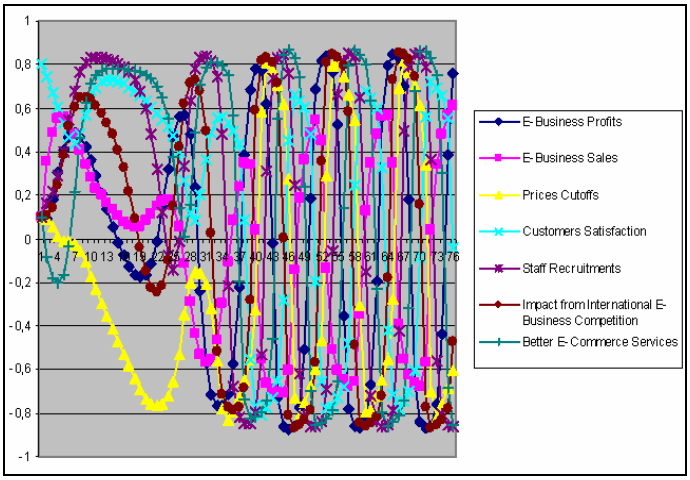

Figure 6. Simulation of e-commerce company model for scenario #4, ($w_{63} = 0.2$, limit cycle)

To study more the affect of this strategic planning action, another similar scenario can be introduced (scenario #5). At this scenario, the way that the "impact of international e-business competition" affects the e-company's price cutoffs are much (higher w_{63} from 0.2 is set to 0.8). The dynamical behaviour of this scenario appears to figure 7. The system after a long transition phase reaches an equilibrium point. The activation levels of model's concepts at equilibrium are presented at Table 4.

E-Business Profits	E-Business Sales	Prices Cutoffs	Customers Satisfaction	Staff Recruitments	Impact from International E-Business Competition	Better E-Commerce Services
0,470	0,790	0,500	0,863	0,708	0,303	0,702

Table 4

The first that we should mention is that now a equilibrium is found in contrast with the limit cycle behaviour of scenario #4 where w_{63}=0.2. Comparing the new equilibrium point with that of scenario #3, we see that the change of weight w_{63} led to higher prices cutoffs (0.500 compared to 0.245 of scenario #3), lower impact from international e-business competition (0.303 compared to 0.438 of scenario #3) and almost the same e-business profits (0.470 compared to 0.459 of scenario #3). This can be important conclusion from e-business company's managers, in the way that they plot the e-commerce strategy.

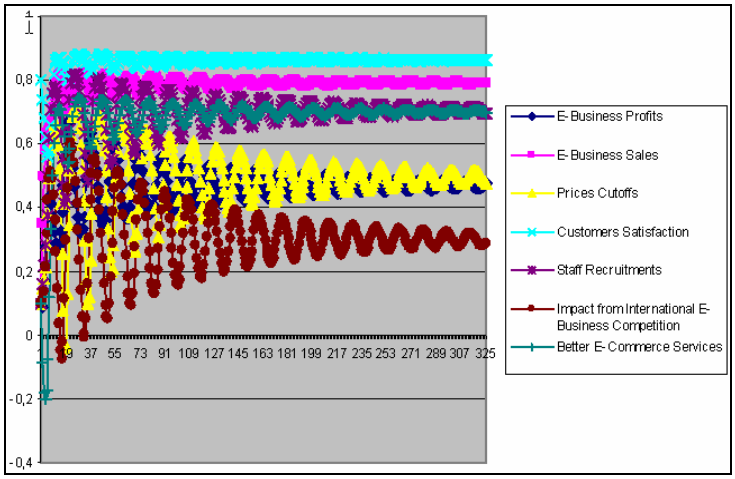

Figure 7. Simulation of e-commerce company model for scenario #5, ($w_{63} = 0.8$, equilibrium)

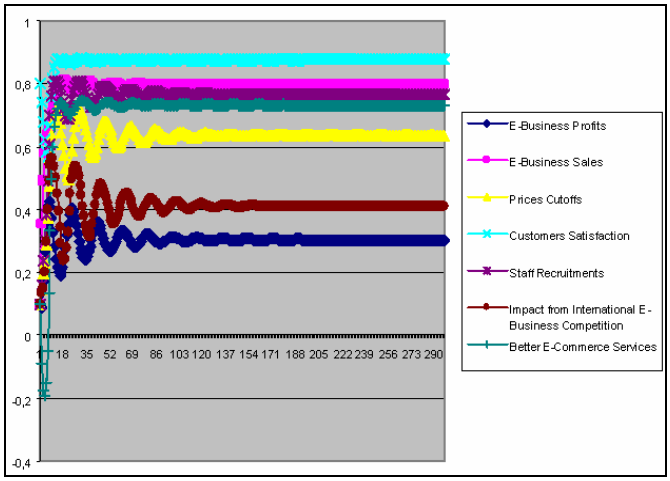

Figure 8. Simulation of e-commerce company model for scenario #6,
($w_{63} = 0.8$, $w_{76} = 0$, equilibrium)

The last scenario (scenario #6) introduced to the system is a combination of scenarios #2 and #5 having $w_{63} = 0.8$ (as in scenario #5) but setting weight w_{76} to 0 meaning that there is no direct influence from concept "Better e-commerce Services" to concept "Impact from International e-business competition" (as in scenario #2). The dynamical behaviour of scenario #6 appears to figure 8. The system after a transition phase reaches a equilibrium point. The activation levels of model's concepts at equilibrium are presented at Table 5.

E-Business Profits	E-Business Sales	Prices Cutoffs	Customers Satisfaction	Staff Recruit-ments	Impact from Interna-tional E-Business Competition	Better E-Commerce Services
0,305	0,796	0,636	0,875	0,766	0,410	0,733

Table 5

Comparing the new equilibrium point with that of scenario #5, we see that the change of weight w_{76} led to even higher prices cutoffs (0.636 compared to 0.500 of scenario #5), higher impact from international e-business competition (0.410 compared to 0.303 of scenario #5) and almost the less e-business profits (0.305 compared to 0.470 of scenario #5). It can be said that certain strategic movements can not bring the initial predicted outcome and this makes FCM technique very useful.

4 Summary - Conclusions

In this paper the strategic planning capabilities of FCM structure were examined, using an FCM model concerning an e-business company. Various scenarios that could be presented by company's managers were introduced to the model and through computer simulations, predictions were made. The representing and strategic planning capabilities of the FCM structure were presented.

The FCM technique was identified as a useful Strategic Planning tool, since it is capable to provide support to company's managers, by making predictions on various scenarios that are imposed to the FCM model. The use of a FCM model is highly appreciated when managers can test their strategic movements, by applying them to the FCM and see the consequences to the concepts of the model. The uncertainty handling capabilities of the FCM structure make also the technique suitable for business decisions were uncertainty and fuzziness exist.

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Appendix A: Weight Matrix of e-Business Company FCM Model

Concepts / Weights	C1	C2	C3	C4	C5	C6	C7
C1: High Profits	0	0,9	-0,4	0	-0,5	0	0
C2: Customer Satisfaction	0	0	0,7	0,8	0	-0,7	0
C3: High Sales	0	0	0	0	-0,2	0,8	0
C4: Internal Affairs	0	0,2	0,7	0	0	0	0,9
C5: E-Promotion	0	0	0	0	0	0,8	0
C6: E-Competition	0,9	0	-0,3	0	0	0	0
C7: Lower Prices	0	0	0	-0,3	0,7	0	0