USING FUZZY COGNITIVE MAP BASED ON STRUCTURAL EQUATION MODELING FOR DESIGNING OPTIMAL CONTROL SOLUTION FOR RETAINING ONLINE CUSTOMERS

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ABSTRACT

Many researchers have proposed behavioral models by using Structural Equation Modeling (SEM) technique. SEM can be used to perform a holistic explanation for causal relationship of latent variables in specific domain problem. However, the causal models retrieved from SEM are still vague for decision makers to identify the optimal control. This study proposes the use of Fuzzy Cognitive Map (FCM) to design optimal solution for the case study of online customer retention. FCM knowledge causality based on SEM is represented by a square matrix called adjacency matrix. After the input vectors for each states are performed with the adjacency matrix, website managers can determine the optimal solution to activate the customer retention program. The final evidence shows that e-Commerce website should provide a typical system and assurance process to guarantee good customer perception in website service quality.

Index Terms—*Causal inference; Fuzzy cognitive maps; Structural equation modeling; e-Commerce; Online customer retention*

1. INTRODUCTION

Nowaday, shopping online is very easy with just one mouse click. Consumers worldwide can find products or services that they are interested at anytime and from anywhere. This benefits of e-Commerce (EC) not only provide for consumers but also offer new market opportunities for entrepreneurs. Small or large firms around the world can start up EC websites with minimum cost. However, retaining online customers is very difficult to manage and organize. Online customers can switch from one site to another very easily and the decision to change or not change is primarily based on trustworthiness of an online vendor. Reichheld and Schefter [1] argued that trust is a vital key to keep long-term relationship with online customers.

In previous studies, researchers have demonstrated that online purchasing intention is the product of both technology adoption and trust in the online vendor [2-4]. The causal relationship between technology adoption, trust, and purchasing intention can be evaluated by using Structural Equation Modeling (SEM). SEM is a statistical technique that has been used widely to examine the structure and strength of latent variables in causal model, but the results of SEM analysis is still vague for decision makers to identify the practical control solution. SEM is not performed well to clarify what-if scenario like “What happens to purchasing intention if we drop security or privacy from causal model?”. But this scenario can be elucidated by using Fuzzy Cognitive Map (FCM).

In this paper, we propose the FCM approach to clarify optimal solution for retaining online customer by using causal model that draw from SEM. We perform FCM with the integrated trust and TAM model. Through FCM approach, we can simulate the effect of input vector in each specific state. Each output vector is shown as the exact value, it is very practical for EC managers to identify the optimal control solution.

The organization of this paper is as follows: in section 2, we briefly review the background of integrated trust and TAM model and FCM approach. In section 3 and 4, we describe the research methodology and research results. In section 5 and 6, we summarize the research discussion and conclusion. Finally, section 7 is the future research.

2. RESEARCH BACKGROUND

2.1. Integrated Trust and TAM Model

Online customers are faced not only with IT usage but also uncertainty in the online environment. Both trust and TAM have a major impact on purchasing intention. Perceived trust plays a crucial role in helping to reduce uncertainty in online exchange relationship. TAM constructs, perceived usefulness and perceived ease of use are the primary driven for EC adoption [3-6]. Chiu et al. [3] also examined that online shopping are related with utilitarian judgment (perceived usefulness), hedonic judgment (perceived each of used, playfulness of shopping online), and uncertainty judgment (trust). In this research, the integrated trust and TAM model, the widely cited model contributed by Gefen et al. [4], is used to perform as the knowledge representation of online customer retention.

2.2. FCM Approach

FCM introduced by Kosko [7, 8] is a combination of fuzzy logic and artificial neural networks. FCM has been successfully applied in research areas that related to equilibrium analysis and decision support [9-11]. Similary in EC research, FCM also provides a practical guideline for designing EDI controls [12], adjusting the design factors for EC websites [13, 14], and even applying for planning EC strategy [15].

FCM is fuzzy directed graphs where nodes represent concepts and edges represent strength of the relationships. The directed edge W_{ij} shows the weight relationship between C_i and C_j . The edges W_{ij} take values between –1 and 1. W_{ij} = 0 indicates no causality; $W_{ij} > 0$ indicates positive causality; $W_{ij} < 0$ indicates negative causality. A simple FCM with five nodes and six weighted edges is illustrated in Figure 1. The value of edge demonstrates the level of influence between two concepts. The knowledge representation of the model can be presented by a square matrix called adjacency matrix as shown in Figure 2.

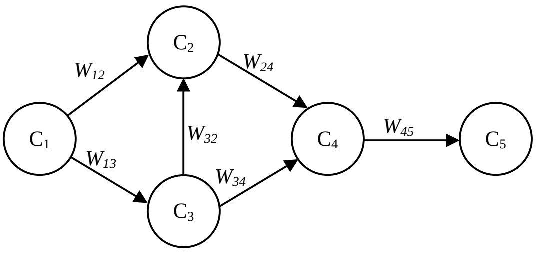

Figure 1. An example of fuzzy cognitive map.

$$E = \begin{bmatrix} 0 & W_{12} & W_{13} & 0 & 0 \\ 0 & 0 & 0 & W_{24} & 0 \\ 0 & W_{32} & 0 & W_{34} & 0 \\ 0 & 0 & 0 & 0 & W_{45} \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure 2. Adjacency matrix of the FCM in Figure 1.

FCM approach allows experts to draw their own causal model, but it is difficult to quantify the weight of causality even from the experts' point of view. Another interesting method is to use the questionnaires to determine causal relationships between the relevant factors. Researchers can identify explicit causal relationships from questionnaires after performing with SEM technique [12, 13, 16].

3. RESEARCH METHODOLOGY

Our research method consists of 4 main steps: 1) configuration of causal relationships, 2) convertion of adjacency matrix, 3) multiplication of input vectors, and 4) identification of the optimal solution.

In step 1, we configure the description of each concept (node) and identify the weight of causality in each edge from the integrated trust and TAM model (contributed by Gefen et al.). The name and description of each node has been described in Table 1, and causal relationships of the integrated trust and TAM model have been illustrated in Figure 3.

In step 2, we draw all values of causality coefficients for each pair of nodes in the adjacency matrix as illustrated in Figure 4.

Table 1. The definition of each concept (node).

Concept	Description	State vector
C_1	Calculative-based	Input
C_2	Structural assurances	Input
C_3	Situation normality	Input
C_4	Familiarity	Input
C_5	Trust	Output level 1
C_6	Perceived ease of use	Output level 1
C_7	Perceived usefulness	Output level 2
C_8	Purchasing intention	Output level 2

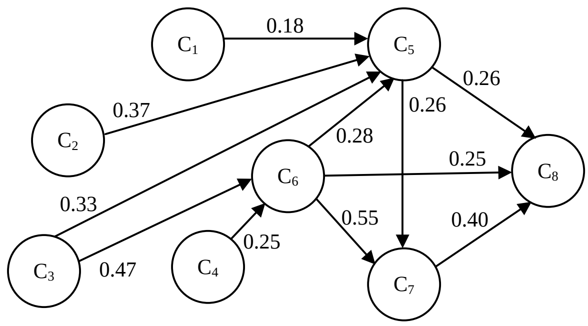

Figure 3. Causal relationships in the integrated trust and TAM model.

$$E = \begin{bmatrix} 0 & 0 & 0 & 0 & 0.18 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.37 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.33 & 0.47 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.25 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0.26 & 0.26 \\ 0 & 0 & 0 & 0 & 0.28 & 0 & 0.55 & 0.25 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.40 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Figure 4. Adjacency matrix of the integrated trust and TAM model.

In step 3, what-if simulation is performed by multiplying input vector in each state with adjacency matrix. The value for each element of the input case can be 1 or 0. Fifteen combination cases of four factors can be provided, the established cases are shown in Table 2.

Table 2. Fifteen cases of input state vectors.

Cases	**Change of status**				**Cases**	**Change of status**			
	C_1	**C_2**	**C_3**	**C_4**		**C_1**	**C_2**	**C_3**	**C_4**
1	1	0	0	0	**9**	0	1	0	1
2	0	1	0	0	**10**	0	0	1	1
3	0	0	1	0	**11**	0	1	1	1
4	0	0	0	1	**12**	1	0	1	1
5	1	1	0	0	**13**	1	1	0	1
6	1	0	1	0	**14**	1	1	1	0
7	1	0	0	1	**15**	1	1	1	1
8	0	1	1	0					

To provide a better understanding, we will demonstrate a multiplication method by using input vector in case 5 as a showcase. Input vector in case 5 is defined as I_5. After multiplying I_5 with matrix E (adjacency matrix), the following result is obtained:

I_5 = (1 1 0 0 0 0 0 0)
$I_5 E$ = (0 0 0 0 0.55 0 0 0) = O_i (iteration 1)

The output state vector from iteration 1 or O_i is an unfinished iteration loop because of the indirect effect, the effect from I_5 can not pass through to the last element of O_i. This causes the last element has no value. To finish this loop, the next iteration must be performed. The input for iteration 2 is the sum of output from level 1 and input of level 1. After performing the vector multiplication in iteration 2, the following result is obtained:

$I_5 + O_i$ = (1 1 0 0 0.55 0 0 0) = O_{ii}
$O_{ii} E$ = (0 0 0 0 0.55 0 0.14 0.14) (iteration 2)

By following the above method, the multiplication in all input cases can be generated and the complete results are shown in Table 3.

In step 4, the optimal control solution is identified by the case that gain a maximum value for the last element (C_8: purchasing intention).

4. RESEARCH RESULTS

By following the research methodology in section 3, we have found that the optimal solution for EC website control is stated in the last case. All input vectors have been activated, that mean all factors have a significant impact to purchasing intention. We can conclude that case 15 is the optimal solution for the integrated trust and TAM model.

Table 3. What-if simulation results with 15 input cases.

Cases	**Input vector**				**Output level 1**		**Output level 2**		
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_8 (%)**
1	1	0	0	0	0.18	0.00	0.05	0.05	**11**
2	0	1	0	0	0.37	0.00	0.10	0.10	**24**
3	0	0	1	0	0.33	0.47	0.34	0.20	**50**
4	0	0	0	1	0.00	0.25	0.14	0.06	**15**
5	1	1	0	0	0.55	0.00	0.14	0.14	**35**
6	1	0	1	0	0.51	0.47	0.39	0.25	**61**
7	1	0	0	1	0.18	0.25	0.18	0.11	**27**
8	0	1	1	0	0.70	0.47	0.44	0.30	**73**
9	0	1	0	1	0.37	0.25	0.23	0.16	**39**
10	0	0	1	1	0.33	0.72	0.48	0.27	**65**
11	0	1	1	1	0.70	0.72	0.58	0.36	**89**
12	1	0	1	1	0.51	0.72	0.53	0.31	**76**
13	1	1	0	1	0.55	0.25	0.28	0.21	**50**
14	1	1	1	0	0.88	0.47	0.49	0.35	**85**
15	1	1	1	1	0.88	0.72	0.62	0.41	**100**

Although the optimal solution is identified in case 15, the strength of each factor does not perform the equal impact. These can be observed through the results in case 1 to case 4. Using factor 1 (calculative-based) alone, the output has been generated at 11%. Using factor 2 (structural assurances) alone, the output has been generated at 24%. Using factor 3 (situation normality) alone, the output has been generated at 50%. Finally using factor 4 (familiarity) alone, the output has been generated at 15%.

Based on Gefen et al. [4] definition: (1) calculative-based beliefs is a belief that the online vendors have more to lose than to gain by cheating behavior, (2) structural assurances is the belief that there are safety mechanisms built into the website, customers can feel safe when doing business with the online vendors, (3) situational normality is the beliefs that website will provide a typical interaction to user, and (4) familiarity is a personal experience about system usage.

Our investigation has shown that situational normality and structural assurances play the most important role for the customers retention program. The empirical evidence has been shown in case 8, both situational normality and structural assurances can bring purchasing intention up to 73%. A typical interaction of website is the first priority that online vendors should be concern. Safety mechanisms and process in a website is the second priority that online vendors should provide for the experienced buyers. There also have some practical guidelines for EC managers that we discuss in the next section.

5. DISCUSSION

The revisitors are familiar with online vendors more than the first time visitors/buyers. The first time buyers concern more about security and privacy than experienced buyers when both of them are encouraged to visit the same website [17, 18]. The revisited customers are not purely concern about security, but they also concern about enjoyment in the website that encourage them [3]. Online vendors should design their website for the revisited customers by providing the typical interacting features such as reasonable search, useful information, and system that easy to use. Online vendors can be achieved the typical web sites concept through a review of successful case from other vendors or through customer focus groups [4]. The typical web sites concept will bring familiarity, good experienced and good reputation in the long term relationship. Not only situation normality but also structural assurances that e-vendors should be responsible for their customers. Assurance process from the website such as safety system, guarantee policy, and contact responsible care will bring faith and trust from customers.

6. CONCLUSION

FCM is fuzzy-graph structure that can represent causal reasoning. FCM approach allows experts to draw their own causal model, but it is difficult even for experts to quantify the weight of causality. In this paper, we have proposed another method to identify the explicit causal relationships in the model by using questionnaires and statistical analysis called SEM. FCM knowledge causality retrieved from SEM is represented by a square matrix called adjacency matrix. We have established the exact weight of causality from the integrated trust and TAM model (contributed by Gefen et al.), and performed what-if simulation for 15 input cases by multiplying each input state vector with adjacency matrix. It is possible for EC managers to perform a lot of practical situations which might occur in reality. The output that can gain a maximum value for the last element is identified as the optimal solution for the model.

In the optimal case, all input factors have a significant impact to purchasing intention. In addition, the weight of input factors can be sorted by priority as follows: situation normality, structural assurances, familiarity and calculative-based. Situation normality and structural assurances are two outstanding factors that play the most important role for the customers retention program. Online vendors should design website that provide both typical interaction and safety process for the customers.

7. FUTURE RESEARCH

We have designed our future work into two directions: First, we continue to improve FCM technique by providing more precise decision in adaptive behavioral phenomenon such as changing state of trust in online vendor from potential customer to repeat customer. For the second direction of research, the intention to purchase has been measured in a subjective way more than objective reality. The coherence between subjective and objective are still difficult to measure both concurrently, we aim to clarify which value of the subjective perception that can be expressed by the value of the objective reality. Thus, the standard features of the website that reflect the real value of customers perception will also be extracted in the future.

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