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Combined structural equation modelling – artificial neural networks model for predicting customer loyalty

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Abstract. Customer loyalty becomes considerations by service providers to maintain for reducing the churn rate. Many studies propose factors that are significantly influencing customer loyalty, and apply them for predicting it. Based on mathematical models, loyalty prediction methods are developed, and it involves new approaches including machine learning. This research aim is predicting customer loyalty using the combination of structural equation model (SEM) and artificial neural networks (ANN). The methodology starts by applying SEM for selecting statistically significant factors affect the loyalty. The linear SEM model ensures this relationship by fulfilling statistical hypothesis and fulfilled assumptions. Once selected factors are found, they are treated as inputs for ANN modelling. ANN is selected because of its ability in nonlinear modelling to enhance its prediction. ANN then learns the relationship between those inputs and the loyalty in real time as any additional observation recorded in. Based on trained ANN, prediction of customer loyalty based on input factors could be done. A case study was conducted at a Hotel by asking 130 customers. SEM inputs includes tangibles, facility, and staff attitudes, while loyalty scores become output. Combination of SEM-ANN has successfully predicted the customer loyalty and brought up chances for improvement strategies.

1. Introduction

Customer loyalty becomes one of important targets in marketing strategies. Many studies discuss about how to improve customer loyalty by practicing customer relationship management. The main reason why this loyalty should be noticed by product or service provider is about its effect on frequent customer purchase exclusively [1], and of course it leads to domination of the market. Once the providers identify factors influencing customer loyalty, then customer service and relationship can be designed [2]. Some quantitative methods have been developed in measuring customer loyalty (see [3]), and some of them focus on predicting customer loyalty. Service or product provider uses this prediction to gain information about what customer relationship strategies should be deployed based on significant influencing factors (see [4]). Moreover, the prediction model can retrieve customer perception data taken from periodic survey to improve individual loyalty prediction, as done by [5]. Some researchers apply mathematical model to predict the loyalty, such as logistic regression [6], discriminant analysis [7], and artificial neural networks [8]. Some of them even combine the prediction model with data mining techniques (see [5]).

However, applying only mathematical model to determine factors influencing the customer loyalty has limitation in updating the fitted model with periodically survey data. Thus, the researcher needs to re-fit the model with new data and re-analyse it based on statistically significant factors. On the other hand, implementing only artificial neural networks (ANN) model for predicting customer loyalty leads to ineffectiveness, where this model involves all the factors without considering their statistical significance. The absence of these such statistical hypothesis also leads the ANN to black-box modelling which is hard to be interpreted by researchers.

The objective of this research is to propose alternative framework in combining the mathematical structural equation model (SEM) for determining factors influencing the customer loyalty with prediction techniques of it based on artificial neural networks (ANN). This framework applies iterative ANN fitting based on updated customer survey data to improve the prediction accuracy. Along with the amount of data collected by survey periodically, this iterative procedure forms simple data mining technique in loyalty prediction.

2. Literature review

2.1. Customer loyalty

In [9], it is mentioned that customer loyalty is a customer emotion that comes to the product or service provider, in spite of the presence of another competitor, more financially lucrative offers on the market. Providers should create strategies to improve this loyalty by determining specific factor, action, and activities to increase the indicator values of loyalty. Predicting customer loyalty could be useful for designing customer relationship management and improving customer perception about benefits they received from service or product providers [10].

2.2. Structural equation modelling (SEM)

Since firstly proposed by Sewall Wright at 1921, structural equation modeling (SEM) has become important tools for understanding relationship between latent and indicator variables in terms of reflective and formative causality.[11]. An example of simple SEM is shown in Figure 1.

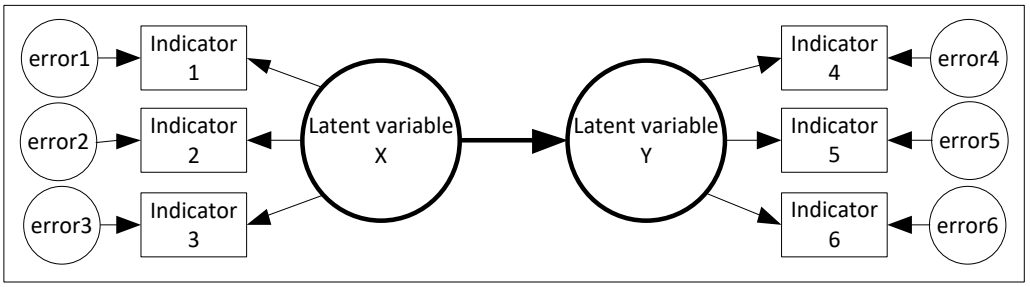

Figure 1. Simple SEM model

In this research, SEM model takes part in determining significant factors or variables that affect the customer loyalty. Indicator variables are measured by valid and reliable questionnaire taken from survey activity. Theses significant factor are then treated as input in ANN model for loyalty prediction.

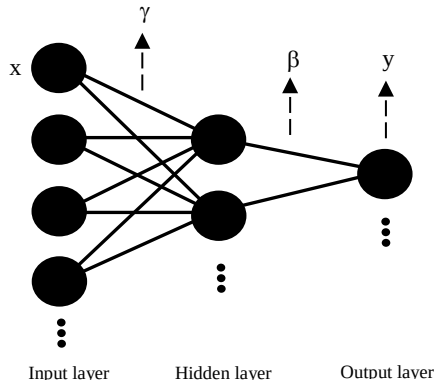

Figure 2. Single hidden layer ANN model

2.3. Artificial neural networks model (ANN)

Many studies apply ANN for several purposes, and some of them use it as part of data mining system (see [12]). It is a complex mathematical model that has flexibility for modelling nonlinear causality among variables, and some literatures categorize it as an artificial intelligence model [13]. However, ANN didn't provide any statistical hypothesis testing for their input variables, and modelling process lead to black-box analysis [13]. General ANN architecture with single hidden layer that is used in this research shown in Figure 2. Each node in a layer is connected (as weights) with another node at the closest layer. A general mathematical model of ANN is shown in equation (1)

$$\boldsymbol{y} = \sum \boldsymbol{\beta_j}\, \boldsymbol{f}\left(\sum \boldsymbol{\gamma_{ij}} \boldsymbol{x_i}\right) + \boldsymbol{\varepsilon} \tag{1}$$

Where i represents the number of inputs, j expresses the number of hidden nodes, and function f represents pre-determined activation function which commonly uses logistic function. The ANN learning or training process estimates the weights γ_{ij} and β_j based on observed input (x) and output y (target) variables. Once the weights are estimated, then this model uses new observed input data to predict its output. Some papers have successfully combined the SEM and ANN to predict such targeted variable based on questionnaire responses (see [14] and [15])

3. Proposed framework

The proposed customer loyalty prediction framework consists of four steps including iterative ANN weight updating process. Charted steps are shown in Figure 3.

- First step: research on customer loyalty should be conducted based on ordinary survey using pre-determined variables potentially influence the loyalty. Next, all observed survey data leads the fitted SEM model to find significant X variables that affect customer loyalty (Y variable).
- Second step: all significant X variables obtained from SEM are then treated as input for ANN model. ANN learning process also involves Y variable as response or targeted output. The ANN produces weights which is used to predict of customer loyalty.
- Third step: as new customer comes and fills the questionnaire, the provider could predict the loyalty based on his/her answer using ANN prediction. Every new recorded data from new customer gives information for the ANN to update its weights and improve prediction accuracy
- Fourth step: ANN would update the weights by using re-learning process as new customer data recorded. Once the weights updated, ANN uses these new weights to predict loyalty of another new customer, and then again update the weights iteratively.

The framework involves iteratively updating ANN weights, the more data from new customer will then result to more accurate loyalty prediction. These steps form simple data mining process for customer loyalty prediction based on combination between SEM and ANN model.

4. Implementation result

4.1. SEM modelling

The framework in figure 2 takes case study on a digital printing service provider. Twenty variables are shown in Table 1, measured in Likert scale questionnaire filled by 100 customers that have been using this service. All predictor variables are involved in SEM model to find the significance ones. The SEM path model is shown in figure 4. Based on common analysis in SEM on some statistical goodness of fit test including Akaike's Information Criterion (see [16]), significance predictors are then chosen. ANN modelling needs these predictors as input to predict customer loyalty.

4.2. ANN modelling

As significance predictor variables was determined by SEM modelling, ANN started the learning process by first created its architecture (see figure 5). As shown in Table 1, there are 8 predictor which should be involved in ANN, including two dimensions. This information is needed by ANN to set the input layer with 8 nodes, and to set the single hidden layer with two nodes. The learning process was then started with back-propagation algorithm [13], and the weights result is shown in Table 3. The Akaike's Information Criterion (AIC) was also used to compare model performance between ANN and SEM.

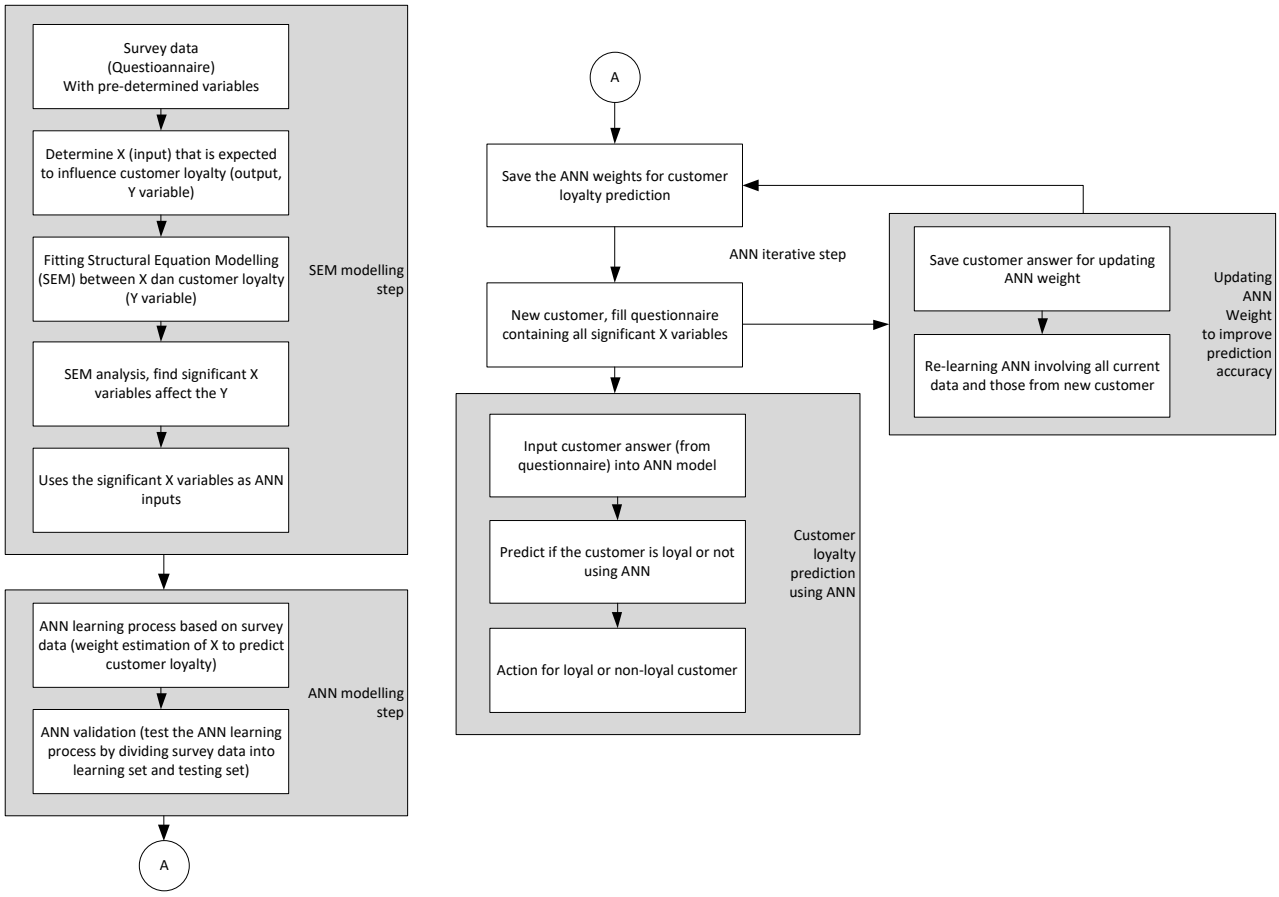

Figure 3. Proposed SEM-ANN framework

Table 1. Predictor and response variable in SEM

ID	Variable	Code	Predictor Significance		Variable dimension	Dimension Significance	Goodness of fit
1	Various service	M1	No				
2	Latest technology equipment	M2		Yes			
3	Price according to quality	M3		Yes			
4	Competitive price	M4	No				
5	Friendly staffs	M5	No				
6	Experienced staffs	M6		Yes			
7	Responsive staffs	M7	No		Marketing mix dimension (predictors)	Significant	Akaike's Information Criterion (AIC) for SEM model -19.378
8	Effective promotion	M8	No				
9	Easy access information	M9	No				
10	Modern interior design	M10		Yes			
11	Clean and comfort environment	M11	No				
12	Strategic location	M12	No				
13	Easy to find location	M13	No				
14	Simple order procedure	M14	No				
15	Monitored order progress	M15		Yes			
16	Satisfaction for service provided	S1		Yes			
17	Fulfilling customer expectation	S2		Yes	Satisfaction dimension (predictors)	Significant	
18	Customer comfort and trust	S3		Yes			
19	Empathy and care	S4	No				
20	Excellence service	S5	No				
21	Response (target) variable	T1	Customer loyalty				

4.3. Customer loyalty prediction

New three customer with new answer then asked with only statistically significant variables, because SEM model has selected them for ANN inputs, and remove insignificant ones. Answers shown in Table 2. These new data then becoms input in learned ANN to predict the loyalty (see Table 3).

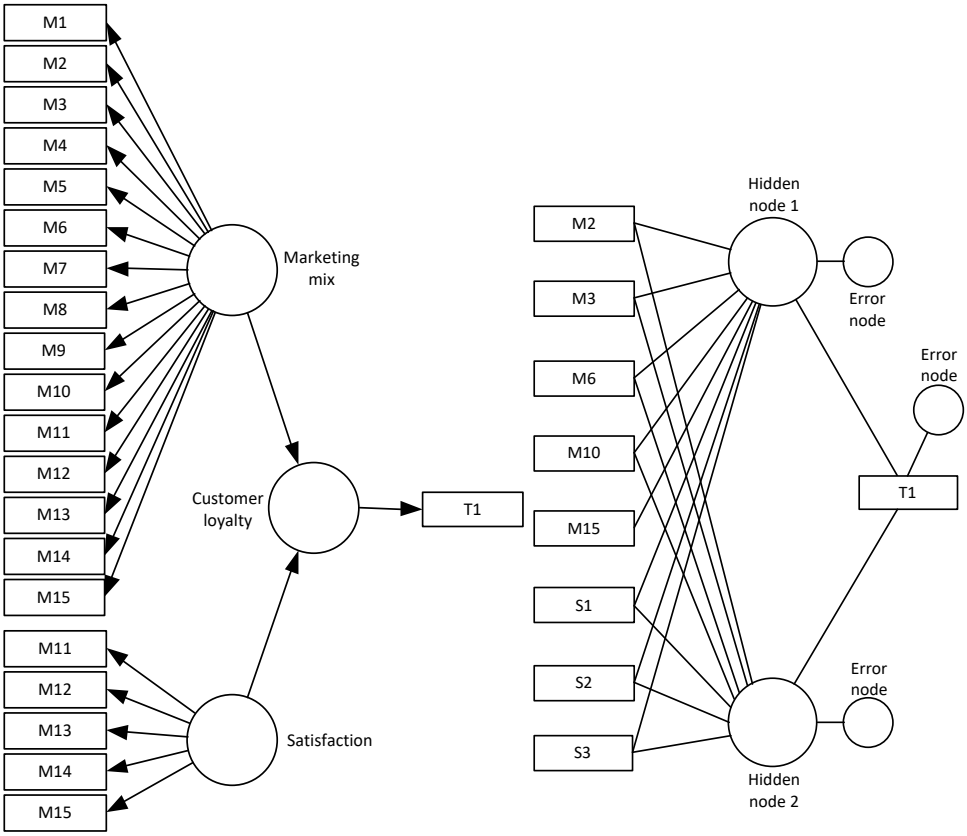

Figure 4. SEM path model

Figure 5. ANN path model

Table 2. New customer loyalty prediction by ANN *(8 input nodes, 2 hidden nodes)*

New Customer 1 questions	Answer (Likert scale)	New Customer 2 questions	Answer (Likert scale)	New Customer 3 questions	Answer (Likert scale)
M2	3	M2	3	M2	5
M3	3	M3	3	M3	4
M6	4	M6	4	M6	4
M10	4	M10	4	M10	4
M15	5	M15	4	M15	5
S1	4	S1	5	S1	5
S2	4	S2	5	S2	5
S3	4	S3	5	S3	5
Predicted loyalty	3.08 (loyal)	Predicted loyalty	3.83 (loyal)	Predicted loyalty	4.42 (loyal)

Table 3. Updated ANN weights

ANN path	Previous weights	Weights after updating	ANN path	Previous weight	Weights after updating	Goodness of fit
M2 → hidden unit 1	1.419	0.045	M2 → hidden unit 2	0.834	0.745	AIC for ANN model -48.9398
M3 → hidden unit 1	0.267	0.551	M3 → hidden unit 2	-1.258	0.465	
M6 → hidden unit 1	2.217	-0.23	M6 → hidden unit 2	-0.338	-0.33	
M10 → hidden unit 1	1.409	0.223	M10 → hidden unit 2	-0.571	0.674	
M15 → hidden unit 1	3.153	0.211	M15 → hidden unit 2	2.079	0.326	
S1 → hidden unit 1	1.843	-0.341	S1 → hidden unit 2	0.325	0.152	
S2 → hidden unit 1	0.799	-0.315	S2 → hidden unit 2	-0.028	0.571	
S3 → hidden unit 1	1.228	-0.027	S3 → hidden unit 2	-1.863	0.298	
Hidden unit 1 → T1	0.787	0.218	Hidden unit 2 → T1	-0.472	0.912	

4.4. Updating ANN weights

These data from new customer then become new raw input for ANN in updating the weights. Using similar learning process, ANN then updates the weights and produces new ones, as shown in Table 3. Every new raw data involved in ANN would then update the weights. This iterative procedure is repeated as new customer continuously comes to the provider, and ANN prediction becomes better with more data inputted in. The AIC criterion also shows better (smaller) result than SEM model.

5. Concluding remark

The framework proposed in Figure 3 has been successfully implemented, including iterative procedures to improve prediction accuracy. With additional programming techniques, this framework becomes a simple data mining system to predict customer loyalty, as there are steps for saving customer answer and updating the ANN weights continuously and automatically.

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Preface

Welcome Remarks,
Chair of the Steering Committee

It is a great pleasure to welcome all of you to Bali and to the International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand. The first InCITE has been successfully held in Bali, Indonesia in 2017. We are very delighted to host the second InCITE here in Bali, Indonesia again.

There are more than 75 presentations in this conference. We welcome leading experts not only from Indonesia, but also from different parts of the world. The experts will share the knowledge and experiences in the fields of informatics, technology, science, and engineering. The main theme of this conference is **Enhancing Engineering Innovation Towards A Greener Future** in response to several world challenges including sustainable development, global convergence of information and communications technologies, climate change and global warming as well as the depletion of unrenewable natural resources. We hope this conference will provide you a good opportunity to get to know each other better and consolidate bonds of friendship and mutual trust.

We would like to express our sincere gratitude to the Keynote and Plenary speakers, International Scientific Committee, Steering Committee, and Organising Committee for their huge efforts to make this conference successful.

Thank you all for your support and attendance at InCITE 2019. Please enjoy the conference and Bali !

Asst. Prof. Djuwari, Ph.D.

Preface

Welcome Remarks,
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Welcome to Bali, Indonesia to all delegates and presenters. It is my pleasure and privilege to welcome all of you to the 2nd (second) International Conference on Informatics, Technology, and Engineering 2019 (InCITE 2019) held by the Faculty of Engineering, University of Surabaya (UBAYA) in collaboration with The University of Adelaide, Australia and Sirindhorn International Institute of Technology (Thammasat University), Thailand.

InCITE 2019 has received more than 75 papers to be presented in this conference. All papers represent four following parallel clusters: Green Design and Innovation, Green Manufacturing and Green Processes, Power System and Green Energy Management, and The Role of IT in Innovation Enhancement. Each cluster supports the main theme of the conference, which is **Enhancing Engineering Innovation Towards A Greener Future.** The engineering innovation is the key to increase our awareness in maintaining the sustainable growth and development in the world.

The Organising Committee of InCITE 2019 would like to express our sincere gratitude for the tremendous supports and contributions from many parties. The supports from The Faculty of Engineering of UBAYA, keynote and plenary speakers, our International Scientific Committee, the Steering and Organising Committees are really acknowledged.

The last but not the least, thank you for your supports, enjoy the conference and we hope through this meeting all of you can extend your networks and collaborations.

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PAPER • OPEN ACCESS

Computer vision system for egg volume prediction using backpropagation neural network

J Siswantoro, M Y Hilman and M Widiasri

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Abstract

One important process in egg production is the sorting process to determine the grade of the egg. The volume and mass of the egg are the factors needed in this sorting process. But the conventional way to measure egg volume and mass can damage egg and takes a long time. This paper proposes a Computer Vision System (CVS) to measure egg volume and mass quickly, accurately, precisely without damaging the egg. The disc method is a method used to calculate the volume of an object with a circular cross-section such as an egg. CVS was designed to calculate the volume using the disc method and calculate the egg mass using density and regression models, based on images captured in real-time or images that have been captured previously. The validation process is carried out using 50 egg samples by comparing results from the proposed method with manual measurements. To compare the time needed by CVS and manual measurement, an average test was used. To test the output accuracy of the volume and mass of egg, relative absolute error, ANOVA test, and correlation test were used. Whereas to test the output precision, the coefficient of variation was used. Based on the results of the testing conducted, CVS in the proposed method successfully measuring the volume and mass of egg quickly, accurately, precisely, without damaging the egg.

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