Applied Mathematics & Information Sciences
An International Journal

http://dx.doi.org/10.12785/amis/072L12

Using Fruit Fly Optimization Algorithm Optimized Grey Model Neural Network to Perform Satisfaction Analysis for E-Business Service

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Received: 28 Oct. 2012, Revised: 22 Feb. 2013, Accepted: 25 Feb. 2013
Published online: 1 Jun. 2013

Abstract: In recent years, the automation and electronic system in the logistics industry have become popular topics in management, which consist of five segments, including marketing, logistics, information technology, banking system, and service system in the online stores (B2C & C2C) of the E-Commerce system. This study contains questionnaires and collective information that focus on logistics. In this article, the results of the survey questionnaires regarding the service quality level of the e-business seller will be used first to conduct the Principal Components Analysis; then the FOA Optimized Grey Model Neural Network(FOAGMNN), the Grey Model Neural Network, and Multiple Regression will be further utilized to perform the construction of service satisfaction detection models. Based on the analysis results in this article, the FOAGMNN model has the fastest error convergence and the best classification forecast capability.

Keywords: E-business, principal components, fruit fly optimization algorithm, grey model, neural network, multiple regression

1 Preface

Just a few years ago, if the consumer wants to purchase something, the only place to go is a shopping market, or to get the merchandise through mail. But along with the development of technology and the construction of electronic payment security mechanism, the consumer needs only to use internet shopping system to buy any merchandise the user wants to buy through internet marketing and shopping model, not only tedious management and selling processes are saved, but also it brings win-win situation to both the buyer and the seller. Currently, there are many researches regarding e-business (Damanpour [4]; Gale [6] Hong[10]), however, the most important ring in the internet marketing is logistics service mechanism; hence, how to use safe and effective strategy to send the real merchandise to the buyer's hand will affect directly the consumer's satisfaction and decision behavior.

Therefore, e-business website in Taiwan is selected to perform internet survey questionnaire sending job, and an effective sample of 200 copies is collected. Then, Principal Components Analysis will be done on the question item of survey questionnaire to find out related important factor in the survey questionnaire. Then the related question items of these principal components will be analyzed. Finally, these principal components will be used as independent variables (X), in the mean time, the total satisfaction of logistics service of the seller will be associated as dependent variable (Y) to form sample data and to perform the construction of three e-business service satisfaction detection models such as Fruit Fly Optimization Algorithm optimized Grey Model Neural Network (abbreviated as FOAGMNN), Grey Model Neural Network (abbreviated as GMNN) and Multiple Regression (abbreviated as MR), meanwhile, the advantages or disadvantages of each model will be compared too.

The main structure of this article is as follows: First section will be introduction of the research motivation and objective of this article. Second section will be introduction of Fruit Fly Optimization Algorithm, Grey Model Neural Network and related applied literature.

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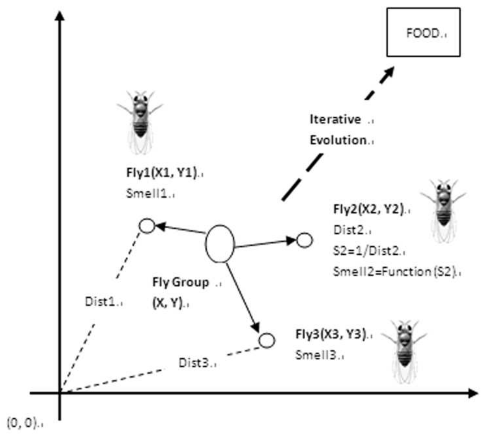

Fig. 1 Illustration of group iterative food searching of fruit fly

Section 3 will be introduction of the sample data used by this article and empirical analysis. Fourth section will be the research conclusion and suggestion.

2 Research method

2.1 New Fruit Fly Optimization Algorithm

In previous studies, most researchers used Genetic Algorithm (Dondeti et al. [5]; Hung et al. [11]; Rovithakis et al. [14]) or Particle Swarm Optimization Algorithm (Cheng et al.[2];Gao et al. [7]; Gudise and Venayagamoorthy [8]; Mohamed et al. [12]; Wang et al. [17]) to optimize parameters of artificial neural network models when constructing their classification and prediction models. By contrast, a brand new approach using New Fruit Fly Optimization Algorithm (NewFOA) is adopted to optimize artificial neural network model in this paper. New Fruit Fly Optimization Algorithm was put forward by Taiwanese scholar Pan [13]. It is a new optimization method based on fruit fly's foraging behaviors and most researchers used NewFOA (Yang et al.[19]; Tu et al.[16]) to optimize parameters of artificial neural network models. Fruit flies are superior to other species in terms of olfactory and visual senses. They can successfully pick up various odors floating in the air with their olfactory organ, some can even smell food sources 40 kilometers away. Then, they would fly to the food. They may also spot with their sharp vision food or a place where their companions gather. Fruit fly's appearance is as shown in Figure 1.

Fruit fly's foraging characteristics have been summarized and programmed into the following steps, which are:

1:Randomly generate a fruit fly swarm's initial position

$$\text{Init X\_axis}; \text{Init Y\_axis}$$

2: Randomly assign each and every fruit fly a direction and distance for their movement to look for food with their olfactory organ.

$$\mathrm{X_i} = \text{X\_axis} + \text{Random Value}$$

$$\mathrm{Y_i} = \text{Y\_axis} + \text{Random Value}$$

Since food's position is unknown, the distance (Dist_i) to the origin is estimated first, and the judged value of smell concentration (S_i), which is the inverse of distance, is then calculated.

$$\mathrm{Dist_i} = \sqrt{(\mathrm{X_i^2} + \mathrm{Y_i^2})}; \ \ \mathrm{S_i} = 1/\mathrm{Dist_i}$$

3: Substitute the judged values of smell concentration (S_i) into the smell concentration judge function (also called fitness function) to get the smell concentrations (Smell_i) of at positions of each and every fruit flies

$$\mathrm{Smell_i} = \mathrm{Function}(\mathrm{S_i})$$

4: Identify the fruit fly whose position has the best smell concentration (maximum value)

$$[\text{bestSmellbestIndex}] = \max(\text{Smell})$$

5: Keep the best smell concentration value and x, y coordinate; the fruit fly swarm will see the place and fly towards the position.

$$\text{Smellbest} = \text{bestSmell}$$

$$\text{X\_axis} = \mathrm{X}(\text{bestIndex})$$

$$\text{Y\_axis} = \mathrm{Y}(\text{bestIndex})$$

6: Enter iterative optimization, repeat steps 2-5 and judge whether the smell concentration is higher than that in the previous iteration; if so, carry out step 6. For detailed source code of the program, refer to the following website:

http://www. oitecshop. byethost16. com/FOA. html

2.2 Grey Model Neural Network

In this article, we refer to Chiang [3], Wang[18] and program code refers to Shi[15] using Grey Model Neural Network to construct e-business service satisfaction classification forecast models [16]. Grey problem means the forecasting problem regarding the development change of the behavioral feature value of grey uncertain system. The original series of the feature value of the uncertain system, that is, $X_t^{(0)}(t = 0, 1, 2, \ldots, N-1)$, after one time AGO (accumulated generating operation), we

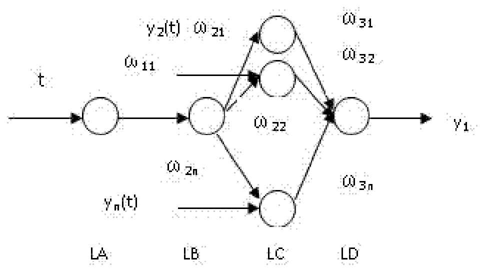

Fig. 2 Grey Model Neural Network topological structure

can obtain new series$X_t^{(1)}$, which shows exponential growth pattern, hence, a continuous function or differential equation can be used to perform data simulation and forecast. For the convenience of expression, the symbol is re-defined, and the original series $X_t^{(0)}$ is represented as $X(t)$, and after one time AGO (accumulated generating operation), the obtained series $X_t^{(1)}$ is represented as $Y(t)$, and the forecast result $X_t^{*(0)}$ is represented as $Z(t)$.

The differential equation of Grey Model Neural Network model of n parameters is expressed as:

$$\frac{dy_1}{dt}+ay_1=b_1y_2+b_2y_3+\cdots+b_{n-1}y_n. \tag{1}$$

In the equation, $y_2,\ldots,y_n$ is system input parameter; y_1 is system output parameter; $a,b_1,b_2,\ldots,b_{n-1}$ are differential equation coefficients.

The reaction time of equation (1) is:

$$z(t)=\left(y_1(0)-\frac{b_1}{a}y_2(t)-\frac{b_2}{a}y_3(t)-\cdots-\frac{b_{n-1}}{a}y_n(t)\right)e^{-at}+\frac{b_1}{a}y_2(t)+\frac{b_2}{a}y_3(t)+\cdots+\frac{b_{n-1}}{a}y_n(t) \tag{2}$$

Let $d=\frac{b_1}{a}y_2(t)+\frac{b_2}{a}y_3(t)+\cdots+\frac{b_{n-1}}{a}y_n(t)$
Equation (2) can be transformed to equation (3)

$$z(t)=\left((y_1(0)-d)\cdot\frac{e^{-at}}{1+e^{-at}}+d\cdot\frac{1}{1+e^{-at}}\right)\cdot(1+e^{-at})=\left((y_1(0)-d)-y_1(0)\cdot\frac{1}{1+e^{-at}}+2d\cdot\frac{1}{1+e^{-at}}\right)\cdot(1+e^{-at}) \tag{3}$$

When the transformed equation (3) is mapped to an expanded BP neural network, we can then obtain Grey Model Neural Network of n input parameters and 1 output parameter. It is as shown in Figure 2:

Here, t is input parameter serial number; $y_2(t)$, ..., $y_n(t)$ are network input parameters; ω_{21}, ω_{22}, ..., ω_{2n}, ω_{32}, ..., ω_{3n} are network weighting values; y_1 is network forecast value; LA,LB,LC,LD are used to represent respectively four layers of Grey Model Neural Network.

Let $\frac{2b_1}{a}=u_1$, $\frac{2b_2}{a}=u_2$, $\frac{2b_{n-1}}{a}=u_{n-1}$, then the network initial weighting value can be represented as:

$$\omega_{11}=a,\omega_{21}=-y_1(0),\omega_{22}=u_1,\omega_{23}=u_2,\ldots,\omega_{2n}=u_{n-1}$$
$$\omega_{31}=\omega_{32}=\cdots=\omega_{3n}=1+e^{-at}$$

In LD layer, the threshold value of the output node is:

$$\theta=(1-e^{-at})(d-y_1(0))$$

The learning process of Grey Model Neural Network is as in the following:

Step 1: Follow the training data feature to initialize network structure and to initialize parameters a, b, meanwhile, a, b values are used to calculate u.

Step 2: Follow network weighting definition to calculate

$$\omega_{11},\omega_{21},\omega_{22},\ldots,\omega_{2n},\omega_{31},\omega_{32},\ldots,\omega_{3n}$$

Step 3: For each input series $(t,y(t)),t=1,2,3,\ldots,N$, calculate the output of each layer

LA layer: $a=\omega_{11}t$
LB layer: $b=f(\omega_{11}t)=\frac{1}{1+e^{-\omega_{11}t}}$
LC layer: $c_1=b\omega_{21}$, $c_2=y_2(t)b\omega_{22}$, $c_3=y_3(t)b\omega_{23}$, ..., $c_n=y_n(t)b\omega_{2n}$
LD layer: $d=\omega_{31}c_1+\omega_{32}c_2+\cdots+\omega_{3n}c_n-\theta_{y1}$

Step 4: Calculate the error between network forecast output and expectation output, and follow the error to adjust weighting value and threshold value.

LD layer error: $\sigma=d-y_1(t)$.
LC layer error: $\sigma_1=\sigma(1+e^{-\omega_{11}t})$,
$\sigma_2=\sigma(1+e^{-\omega_{11}t})$, ..., $\sigma_n=\sigma(1+e^{-\omega_{11}t})$.
LB layer error:

$$\sigma_{n+1}=\frac{1}{1+e^{-\omega_{11}t}}\left(1-\frac{1}{1+e^{-\omega_{11}t}}\right)(\omega_{21}\sigma_1+\omega_{22}\sigma_2+\cdots+\omega_{2n}\sigma_n)$$

Follow forecast error to adjust the weighting value.

Adjust the connection weighting value from LB to LC.

$$\omega_{21}=-y_1(0),\omega_{22}=\omega_{22}-\mu_1\sigma_2b,\ldots,\omega_{2n}=\omega_{2n}-\mu_{n-1}\sigma_nb.$$

Adjust the connection weighting value from LA to LB:
$\omega_{11}=\omega_{11}+at\sigma_{n+1}$.
Adjust threshold value: $\theta=(1+e^{-\omega_{11}t})\left(\frac{\omega_{22}}{2}y_2(t)+\frac{\omega_{23}}{2}y_3(t)+\cdots+\frac{\omega_{2n}}{2}y_n(t)-y_1(0)\right)$.

Step 5: Judge whether the training is ended or not, if not, go back to Step 3.

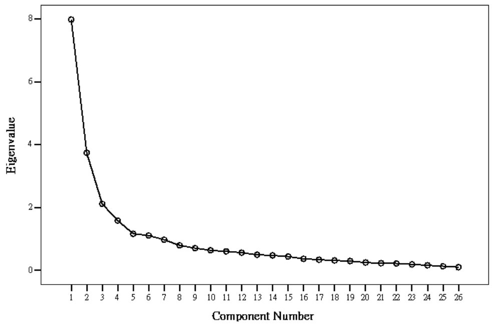

Fig. 3 The Eigen value trend chart of each principal component in Principal Components Analysis result

3 Empirical study

3.1 Sample data and variable

In this research, e-business website is selected to send the internet survey questionnaire for logistics satisfaction survey, and the survey time is from Jun 01, 2009 to Aug 31 for a period of two month. For survey questionnaire, a total of 200 effective samples are collected. All these samples are from e-business sellers. In the age structure of the sample data, about 70% of the sample has age below 30 years old; the gender is mostly female (70.45%); for the residence place, it is respectively northern Taiwan (5%), middle Taiwan (22%), southern Taiwan (19%) and eastern Taiwan (9%); more than 35% person under interview says that they have more than three years of online auction sale experience, and people with more than one year online auction sale experience occupies about 83% of the entire sample. in the logistics method selection aspect, post office has the highest proportion (67%), the next is t-cat express mail (16%), Taiwan Pelican Express Co., Ltd. (13%), and other logistics model only occupies about 4%.

In this article, 26 question items in survey questionnaire for satisfaction survey are adopted in Principal Components Analysis, from Principal Components Analysis results, the selected principal components are based on Eigen value larger than 1. Figure 3 shows the location of each principal component relative to the Eigen value of vertical axis, wherein the Eigen values of the first five principal components are all larger than 1, and these five principal components are named respectively as: abnormity handling (X1), business site (X2), service spot (X3), value added service (X4) and delivery speed (X5). In this article, first 4 principal components and 5 principal components are selected respectively as independent variables, meanwhile, they are associated respectively with the question items of logistics entire satisfaction of the auction seller as dependent variables (Y), hence, there are a total of two sets of data to be used for the construction of three e-business service satisfaction detection models performed in the next section, namely, Fruit Fly Optimization Algorithm optimized Grey Model Neural Network, Grey Model Neural Network and Multiple Regression; and the descriptive statistical values of these two sample data are as shown in Table 1. In addition, this article, using dichotomy method, divide the logistics service entire satisfaction from the auction seller into satisfied (Including very satisfied and satisfied, represented by 0, for a total of 100 data) and dissatisfied (Including fair, dissatisfied and very dissatisfied, represented by 1, for a total of 100 data) to be used as reference for future research.

Table 1 Descriptive statistical value of five components and logistics quality and service satisfaction question item

Component	X1	X2	X3	X4	X5
Max	3.08355	3.08908	3.05961	4.5721	6.22018
Min	-2.89468	-2.16388	-5.02899	-3.18589	-3.99229
Avg	6E-07	4.5E-07	-6.5E-07	-1E-07	-5E-08
Std	0.99750	0.99750	0.99750	0.99750	0.99750

3.2 Construction of three e-business service satisfaction detection models

In this article, sample data of two sets with 200 data in each set are finely divided into five small groups, and the data of four small groups are used as training data to construct the model, and one small group of data is used as test data to test the model stability, and a cross verification is thus performed.

First, 5 independent variables of X1-X5 are associated with dependent variable Y to be used as the first set of sample data, then the first four small groups of training data are used respectively to construct three models of FOAGMNN, general GMNN and MR. In the model construction of Fruit Fly Optimization Algorithm optimized Grey Model Neural Network, this article performs Fruit Fly Optimization Algorithm on six most important parameters in Grey Model Neural Network model structure, namely, a, b1, b2, b3, b4 and b5 The random initialization fruit fly swarm six location range is [0,100], the random fly direction and distance zone of iterative fruit fly food searching is [-10,10], fruit fly population size is 20, and iterative number is 100. The way used in the FOA optimized GMNN is to first calculate the distance between the individual location of the fruit flies and the origin coordinate (0, 0), and then calculate the reciprocal. The smell concentration judgment value (S_i) is then calculated, and then substituted into the six parameter of GMNN. After that,

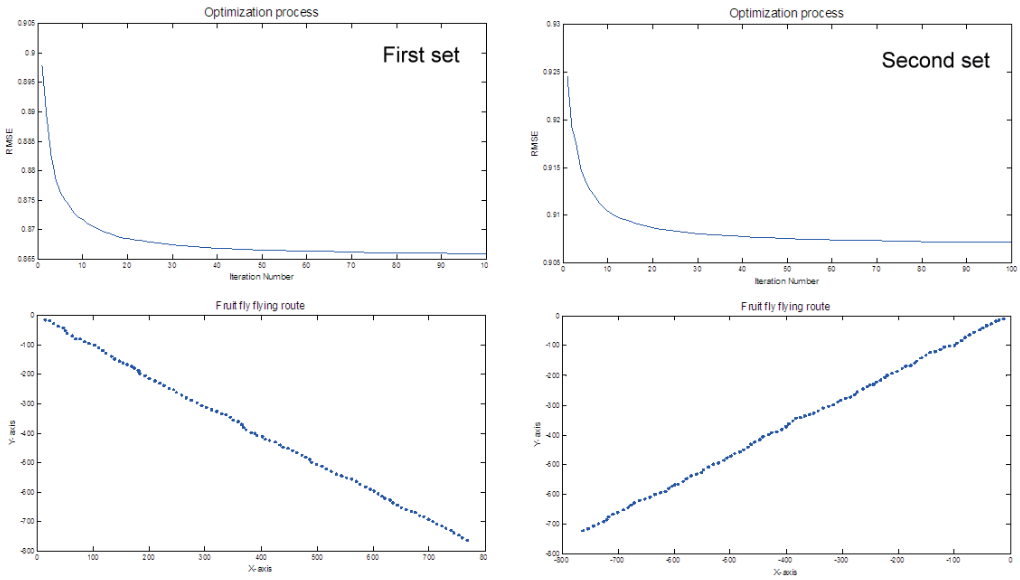

Fig. 4 RMSE evolution trend chart and fruit fly swarm location coordinate route of FOAGMNN

the training data is entered to get the network output value. Then with the target value, RMSE (or called Fitness) is calculated, the smaller the value, the better. Finally, the best six smell concentration judgment value (S_i) is kept to be used as the six parameter value of GMNN, and the iterative search is made based on this method. Through the smell of the fruit fly's random food finding, and through the flocking at the location of the highest concentration of smell using vision, the six parameters value of GMNN can be adjusted to its optimal value, and the RMSE between network output value and target value can be adjusted to the minimal value.

Second, similarly, we also using first 4 principal components (X1-X4) associated with dependent variable Y to be used as the second set of sample data, then the first four small groups of training data are used respectively to construct three models of FOAGMNN, general GMNN and MR. Figure 4 represent the training data of first set and second set, respectively. FOA is used to iteratively optimize the six parameters of GMNN, the RMSE between generated output value and target value, and the trend of the fruit fly swarm flying route. After 100 times of iterative evolution, in first set, convergence can be seen in generation and RMSE value is respectively [93, 0.8659], with six coordinates of (713.6302, -707.7197), (712.8854, -706.4619), (713.9886, -707.1006), (713.7944, -707.7032), (713.4633, -706.5857), (712.7047, -707.6214), and the six parameters (i.e., a, b1-b5) value is respectively [0.6278, 0.3028, 0.3852, 0.6145, 0.6242, 0.6105]; in second set convergence can be seen in generation and RMSE value is respectively [95, 0.9071], with five coordinates of (-720.6606, -684.446 1), (-719.4074, -683.1877), (-721.0486, -683.2271), (-72 1.1286, -684.4320), (-719.5184, -682.7066) and the five parameters (i.e., a, b1-b4) value is respectively [0.5779, 0.3174, 0.3663, 0.5742, 0.6044]

3.3 General analysis on the classification forecast capabilities of three models

Figure 5 is the ROC diagram which shows the cross validation of the classification forecast results of the three e-business service satisfaction detection models using 5 groups of first set and second set sample data, Bradley pointed out that the larger the area under curve (AUC) of a model [1], the more accurate the model's classification capacity. The classification forecast results can be seen clearly from the diagram, which shows that FOAGMNN model has the largest AUC therefore having the best classification capacity. Then, from an observation of the ROC curve analysis output result through Table 2, we see that sensitivity (Sen) refers to the percentage of actual 1s to predicted 1s (i.e. Dissatisfied), while specificity (Spe) refers to the percentage of actual 0s to predicted 0s (i.e. Satisfied); and professor Hand pointed out that Gini Index = 2 $\times$ AUC – 1 [9]. Here, these index values are the larger the better. As shown in the table, for first set FOAGMNN model, the Sen is 0.92, Spe is 0.92, area under the curve (AUC) is 0.92, and Gini Index is 0.84; for second set FOAGMNN model, the Sen is 0.88, Spe is 0.90, the area under curve (AUC) is 0.89, and the Gini Index is 0.78, which are all higher than those of the general GMNN and traditional Multiple Regression model. Therefore, the

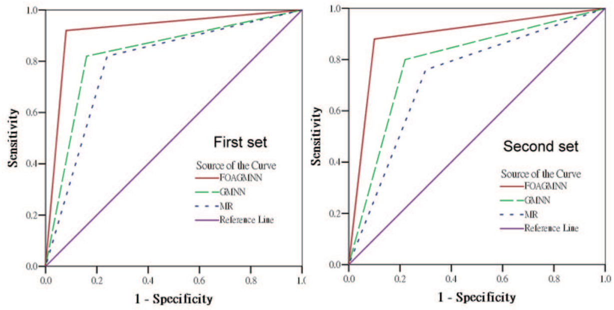

Fig. 5 The ROC curve of the classification forecast result of the three service satisfaction detection models

Table 2 The analysis output result of ROC curve

	Model	Sen	Spe	Auc	Gini
First set	FOAGMNN	0.92	0.92	0.92	0.84
	GMNN	0.82	0.84	0.83	0.66
	MR	0.82	0.76	0.79	0.58
Second set	FOAGMNN	0.88	0.9	0.89	0.78
	GMNN	0.80	0.78	0.79	0.58
	MR	0.76	0.7	0.73	0.46

FOAGMNN model has a very good classification prediction capability.

4 Conclusion

The major contribution of this article is to investigate the survey data of the three e-business service satisfaction detection models of the famous E-Commerce websites in Taiwan. We try to understand the satisfaction level of the seller regarding the entire logistics process of the auction. Then through Principal Components Analysis, the principal components of each question item in the survey questionnaires are also studied. In addition, the principal components and the satisfaction level of the auction seller are further associated to become the sample data for constructing these models. In the meanwhile, three data mining techniques of FOAGMNN, GMNN and MR are adopted respectively to construct the classification forecast models of service satisfaction, and it is hoped that the research results can be used as references by future researchers. In conclusion of this article, it is found that Fruit Fly Optimization Algorithm Optimized Grey Model Neural Network (FOAGMNN) forecast model has the fastest convergence speed in RMSE, and the accuracy of the classification forecast model is also higher than that of other models, which can also be used as references by future researchers.

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