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Fuzzy Delphi and back-propagation model for sales forecasting in PCB industry

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Abstract

Reliable prediction of sales can improve the quality of business strategy. In this research, fuzzy logic and artificial neural network are integrated into the fuzzy back-propagation network (FBPN) for sales forecasting in Printed Circuit Board (PCB) industry. The fuzzy back propagation network is constructed to incorporate production-control expert judgments in enhancing the model's performance. Parameters chosen as inputs to the FBPN are no longer considered as of equal importance, but some sales managers and production control experts are requested to express their opinions about the importance of each input parameter in predicting the sales with linguistic terms, which can be converted into pre-specified fuzzy numbers. The proposed system is evaluated through the real world data provided by a printed circuit board company and experimental results indicate that the Fuzzy back-propagation approach outperforms other three different forecasting models in MAPE measures.

Keywords: Sale forecasting; Fuzzy theory; Neural network; Fuzzy back-propagation network

1. Introduction

The printed circuit board (PCB) industry has grown up with the rapid development of the electronic, information and communication industries recently. During the past 30 years, the PCB industry in Taiwan has been striving to improve the manufacturing techniques, increase the production equipments, and strengthen the quality control, in order to integrate the developments of up-stream, middle stream and down-stream industries. This endeavor had successfully made Taiwan be ranked top 3 in the world for the total production amount of PCB. However, the overall accomplishment of PCB industry has been decreased recently by the influence of the profit conditions of the down-stream industries such as information, communication and consuming electronic industries.

To decrease a cost means to increase a profit. Hence, in order to improve the enterprise's competitiveness, the executives should be able to make correct decisions using the available information, and 'forecasting' is viewed as an important part of decision making. Reliable forecasting of sales can help to make an effective inventory control and a proper scheduling process to increase the usage percentage of machines, which can avoid works being held up for lack of materials. To provide appropriate decisions and help the policy maker judge correctly is the basis of the production planning, with the end of decreasing the overall costs. Thus, all enterprises are working on the exploitation of prediction methods, which decide the success and failure of an enterprise.

When dealing with the problems of sales forecasting, many researchers have used hybrid artificial intelligent algorithms to forecast, and the most rewarding method is the application integrating artificial neural networks (ANNs) and fuzzy theory. This method is applied by incorporating the experience-based principal and logic-explanation capacity of fuzzy theory and the capacity of memory and error-allowance of ANNs, as well as self-learning by numerical data.

This research focuses on the monthly sales forecasting of PCB and applies the fuzzy Delphi to select variables with a better and more systematic way from expert experience. These input variables will be converted into pre-specified fuzzy numbers; aggregated and then fed into the FBPN for monthly sales forecasting, with the purpose of improving

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the forecasting accuracy and using this information to help managers in decision-making.

2. Literature review

Traditional methodologies of sales forecasting can be divided as follows:

1. Qualitative method
   Qualitative method belongs to more subjective approaches, which transform qualitative data into quantitative estimates based on estimations and opinions. This method is best adopted when the available data are not sufficient, e.g. when a new product is introduced to the market. Generally it includes Delphi Method, Market Research, Panel Consensus, Visionary Forecast and Historical Analogy, etc.
2. Time series analysis
   It mainly forecasts the future demands by using the data of demands in the past. In traditional forecasting models, no matter how long the forecasting time takes, it can be done by the available information analyzed through any kinds of statistical methods. The most popular models are Moving Average, Exponential Smoothing, Box Jenkins, and Trend Projections, etc.
3. Cause and effect analysis
   This method adopts the technique of linear regression and attempts to investigate the cause-and-effect relationship between the predicted items and other related factors. This method can be used when the historical data can provide enough information to analyze and explain the relative factors of the forecasting items. The most commonly used models include Regression analysis and Econometric Model, etc.

Although, the above three traditional methods have been proved effective, they still have certain shortcomings. Kuo and Chen (2004) believed that the traditional statistic approaches have higher performance dealing with data of seasonality and trend, but they are inappropriate for unexpected situations. Tang (2003) proposed that the Time Series and Cause and Effect analyses are obviously insufficient when dealing with more complex problems or the reciprocal function between the non-linear system and its factors. Luxh et al. (1996) claimed that many common qualitative models lack the abilities of systematic structure and judgment, which makes the final result imprecise. As discussed by Kuo and Xue (1998), the new developed Artificial Intelligent (AI) models have more flexibility and can be used to estimate the non-linear relationship, without the limits of traditional Time Series models. Therefore, more and more researchers tend to use AI forecasting models to deal with forecasting problems.

Kim and Han (2000) proposed genetic algorithms (GAs) approach to feature discretization and the determination of connection weights for artificial neural networks (ANNs) to predict the stock price index. Experimental results show that GA approach to feature discretization model outperforms the other two conventional models. Chang et al. (2004) proposed a hybrid model for stock price forecasting by integrating Multiple Regression, Back Propagation neural network and an Autoregressive integrated moving average model. Versace et al. (2004) evaluate the performance of a heterogeneous mixture of neural network algorithms for predicting the exchange-traded fund DIA. A genetic algorithm is utilized to find the best mixture of neural networks, the topology of individual networks in the ensemble, and to determine the features set. Chang et al. (2005) developed an Evolving Neural Network (ENN) forecasting model by integrating Genetic Algorithms and Neural Network for sales forecasting in PCB industry. The experimental result shows that the performance of ENN is superior to traditional statistical models and Back Propagation Network. Chang and Lai (2005) proposed a hybrid system to combine the self-organizing map (SOM) of neural network with case-based reasoning (CBR) method, for sales forecasting of new released books.

Delphi Method was first applied to the personnel management of pilots as early as 1985. Recently, the fuzzy concept was embedded in Delphi Method by calculating the average weights of all the factors from the worst to the best degree based on the expert's experience. Chang et al. (2000) mentioned that Fuzzy Delphi Method could be applied to deal with the fuzzy relationship of the predicted items since the fuzzy number of each factor can explain clearly how independent variables are kept in the fuzzy forecasting models. When using Fuzzy Delphi Method to select the evaluation factors, there are two points needed to be considered: (1) the correctness of the collected factors. (2) The appropriateness of selecting the expert group. Besides, Kaufmann (Kaufmann & Gupta, 1988) mentioned that this method has the following advantages:

1. To decrease the times of questionnaire survey
2. To avoid distorting the individual expert opinion
3. To clearly express the semantic structure of predicted items
4. To consider the fuzzy nature during the interview process.

Fuzzy Theory was proposed in a paper written by professor L.A. Zadeh of U.C. Berkeley, which was published in the journal 'Information and Control' in 1965. Professor Zadeh presented the concept of Fuzzy Sets, which mainly investigates the fixed-quantity method of human's subjective thinking process. After evolving for more than 30 years, fuzzy system has been widely applied to Auto-Control, Pattern Recognition, Decision Analysis, Forecasting, and Time Series Signal Process to this date.

Fuzzy theory is first combined with ANNs by Lin and Lee (1991), who incorporated the traditional fuzzy