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Fuzzy Adaptive ELM Approach for Supply Chain Management

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Abstract: *This paper shows forecasting practices in supply chain management (SCM) in a variety of industries, particularly in the areas of life sciences, retail chain and consumer products. This paper also presents the scenario of forecasting practices based on secondary data and represent the role of SCM, demand management, collaborative coordination, etc. Accordingly, highlighted in in-depth analysis is presented that opens up new limits to potential researchers and professionals for the use of forecasting techniques. In this paper a fuzzy adaptive extreme learning model is proposed for demand forecasting of shoe sale.*

Keywords: *Supply Chain Management, Fuzzy logic, ELM, Forecasting*

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I. Introduction

Demand and sales forecasting is one of the most important functions of manufacturers, distributors, and trading firms. Keeping demand and supply in balance, they reduce excess and shortage of inventories and improve profitability [1]. When the producer aims to fulfil the overestimated demand, excess production results in extra stock keeping which ties up excess inventory. On the other hand, underestimated demand causes unfulfilled orders, lost sales foregone opportunities and reduces service levels. Both scenarios lead to inefficient supply chain [2]. Thus, the accurate demand forecast is a real challenge for participant in supply chain. The ability to forecast the future based on past data is a key tool to support individual and organizational decision making. In particular, the goal of Time Series Forecasting (TSF) is to predict the behavior of complex systems by looking only at past patterns of the same phenomenon. Forecasting is an integral part of supply chain management [3]. Traditional forecasting methods suffer from serious limitations which affect the forecasting.

II. Literature Review

Tomas Eloy Salais-Fierro et al. [1] The purpose of this research is to build a hybrid method for integrating demand forecasts generated from expert judgments and historical data and application in the automotive industry. Demand forecasts through the integration of variables; expert judgments and historical data using fuzzy logic and neural network. The methodology includes the integration of expert and historical data applying the Delphi method as a means of collecting fuzzy date.The study aims to focus in manufacturing industry factors in conjunction time series data.

Chandraulet al. [2] revealed the limitation and few practical solutions on forecasting to be useful in the business organization. Consequently, the authors describe recommendation and proposes a model on forecasting management model. This paper highlights in intensive analysis, however, it unlocks further frontiers for the prospective researchers as well as practitioners in order to apply forecasting techniques.

ZeynepHilalKilimci et al. [3] this purpose, historical data can be analyzed to improve demand forecasting by using various methods like machine learning techniques, time series analysis, and deep learning models. In this work, an intelligent demand forecasting system is developed. This improved model is based on the analysis and interpretation of the historical data by using different forecasting methods which include time series analysis techniques, support vector regression algorithm, and deep learning models. To the best of our knowledge, this is the first study to blend the deep learning methodology, support vector regression algorithm, and different time series analysis models by a novel decision integration strategy for demand forecasting approach.

Ping-HuanKuo et al. [4] In this study, an accurate deep neural network algorithm for short-term load forecasting (STLF) is introduced. The forecasting performance of proposed algorithm is compared with performances of five artificial intelligence algorithms that are commonly used in load forecasting. The Mean Absolute Percentage Error (MAPE) and Cumulative Variation of Root Mean Square Error (CV-RMSE) are used as accuracy evaluation indexes. The experiment results show that MAPE and CV-RMSE of proposed algorithm are 9.77% and 11.66%, respectively, displaying very high forecasting accuracy.

ShubhamBhadouria et al. [5] This work to study the basics of Artificial Neural Network (ANN) and its application in supply chain management and develop an ANN model which will predict the future demand with high accuracy as compared to the conventional Forecasting methods. To demonstrate the effectiveness of the present study, demand forecasting issue was investigated on a gear manufacturing company as a real-world case study. Three ANN models with TANSIGMOID, LINEAR and LOGSIGMOID transfer function has been developed using MATLAB software for forecasting the demand.

Rajkumar Sharma, Piyush Singhal [6] presented a case of prediction of sample demands for industrial lubricants. Authors have observed that the demand for most of the industrial lubricants depends on three main factors i.e. quality, cost, and delivery time. These factors are studied and compared with other competitors dealing in similar nature of products. The quality is mapped with three fuzzy parameters viz. inferior, alike, and superior. The cost is linked with three linguistic variables viz. low, identical & high.

Gunawan et al. [7] aimed to design an application to determine the sub-criteria weight with Fuzzy-AHP method, select the best supplier via Fuzzy-TOPSIS method, and calculate the allocation of quota to each supplier thru Fuzzy-MOLP method. Simulation confidently demonstrates that the Fuzzy-AHP approach is able to be operated to generate parameter Quality Product as the best sub-criteria (with value 0.221), the Fuzzy-TOPSIS technique can be used to ring out the supplier (where CV. Maju Jaya Abadi as the best supplier), and the method Fuzzy-MOLP is exploited to calculate the allocation of quota (where CV. Maju Jaya Abadi as a supplier with the highest percentage of 44.40%).

Mohamed Mira. [8] presented fuzzy logic along with the economic order quantity to model demand and supply uncertainties in automobile industry. Order quantity was considered as the output of the model. Linguistic values were used to represent both inputs and output. Fuzzy rules were set based on the experience of a group of supply chain members. Results show a huge reduction in the total inventory cost, compared to the current model. In addition, no shortage occurred in the proposed fuzzy model.

III. Supply Chain Management Techniques

Supply chain is a network which includes some companies and sectors. In this network, the material is acquired and processed into intermediate or finished products, and finished products then are sent to the users. Therefore, it can be seen as a multi-level system , including production , distribution, retail and other sectors. Supply chain management means that through designing, planning and controlling the supply chain, logistics, information flow and capital flow, a balance between supply and demand is achieved, customer satisfaction is improved, and overall operating costs of the supply chain is reduced. Based on the foregoing characteristics, neural networks currently applied in the supply chain management are mainly in the following three areas: optimization, forecasting and decision support.

A. Optimization

Neural network is the most popular computing technology to solve the optimization problems. It has an important significance for supply chain management. Currently, it has been studied how to apply neural networks to solve the supply chain management optimization problem, such as shop scheduling, warehouse management, selection of transportation route and so on. Some of these problems are the core problems to build the logistics information system of the enterprise. In addition, compared with other technologies, neural network has a strong adaption ability, and it can promptly consider and accommodate emerging constraints with real-time processing capabilities.

B. Forecasting

For a long time, uncertainty is the biggest obstacle for company decision-makers. The uncertainty in supply chain comes mainly from changes in product demand, delivery delays and mechanical failures Because of the inaccurate forecasting for the local aspects of the supply chain, the overall supply chain will have a big fluctuation and this volatility will progressively enlarge. Thus, how to improve the forecasting accuracy and minimize the uncertainty of supply chain management has become the core issue. As we all know, the information supporting our decision-making generally is not sufficient, which has become the insurmountable obstacles of other forecasting techniques such as expert systems, statistical methods, and time series. But the black box function in neural network can avoid this obstacle, and obtain a more satisfactory forecasting result. Furthermore, the neural network is essentially a nonlinear system. Many of the supply chain forecasting problems are more complex, non-linear problems, which the linear forecasting tools are powerless, while the neural network is even easier.

C. Decision Support

When managers are making decisions, there are two problems they are facing. One is that the decision-making information is too large, and the other is that the decision-making information is incomplete. As mentioned earlier, they are serious impediment to the application of expert systems, statistical methods. In contrast, the neural network simulates the human brain thinking. To some extent, It has a "creativity ", so that it can make more rational and informed decisions only with the incomplete information. Now, most of the research for decision support system focused on the management and analysis of the decision-making data. Due to the neural network's unique identification ability, data classification capabilities and self-organizing capabilities, it becomes the ideal data search technology in supply chain management. A neural network system for determining the potential customer in the sales process has been developed. Another important issue the decision support system faced is how to find the intrinsic relationship between the data from the huge data. Self-organization and generalization capabilities of the neural networks become a powerful tool for solving this problem.

IV. Objectives of Research Work

1. This work is designed for shoe demand forecasting.
2. Weekly demand forecasting will be performed.
3. Which items is frequently demanded will be analyzed.
4. With respect to item which size is generally used will be analyzed.
5. Which item will be demanded in which particular season/month with be analyzed.
6. Reduction of shortfall will be done by applying Fuzzy logic approach. So that wastage of item will be minimized.

V. Approach Used

The methodology is based on fuzzy adaptive extreme learning machine, has universal approximation capability and thus is used extensively for function approximation. Learning capability of neural networks and knowledge representation of fuzzy are combined in ELM network. This model uses Takagi–Sugeno–Kang (TSK) fuzzy inference system which gives accurate models. Fuzzy adaptive Extreme learning machine has shown good results for regression problems.

Algorithm

Given:
n = Number of weeks
m = Number of items
t= Number of sizes available
a= Number of iterations
fori=1:n
for j=1:m
for k=1:t
for x=1:a
Forecast Demand (F_d)
Calculate Error
If error > threshold value
Update internal parameters of algorithm
else
Final forecasted demand= F_d
end
end
end

The proposed methodology works in different levels as discussed below:

i. The dataset is taken.
ii. Select Parameters for Fuzzy Rule Designing.
iii. Weekly Forecasting Demand for Different Shoe Size with item Code.
iv. Determine the shortfall for future weeks.

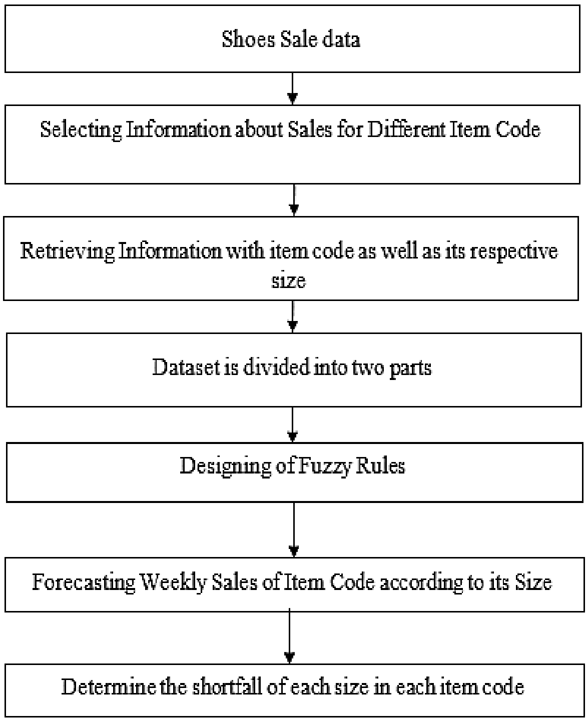

Figure 1: Flow Chart of Proposed Methodology

Figure 2 shows architecture of Fuzzy Adaptive Extreme Learning Machine network.
There are five layers: input layer, firing strength computational layer, firing strength normalization layer, consequent parameter layer, and output layer.

Input layer

Nodes of this layer represent an input variable.

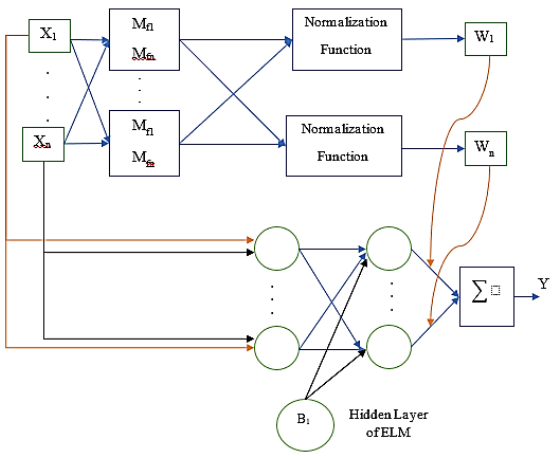

Figure 2: Fuzzy Adaptive Extreme Learning Machine

Fuzzification layer

This layer consists of L clusters which represents the L fuzzy rules. Each cluster has n nodes representing the fuzzy membership functions for n inputs. Two-sided Gaussian functions are used as the membership functions for this network. The mathematical expression for two-sided Gaussian functions is :

$$g(x_j, c_{ijL}, \sigma_{ijL}, c_{ijR}, \sigma_{ijR}) = \begin{cases} e^{\frac{-(x_j - c_{ijL})^2}{2\sigma_{ijL}^2}}, & x_j < c_L \\ 1, & c_L \le x_j \le c_R \\ e^{\frac{-(x_j - c_{ijR})^2}{2\sigma_{ijR}^2}}, & x_j > c_R \end{cases}$$

where c_{ijL}, σ_{ijL}, c_{ijR}, and σ_{ijR} are the premise parameters.

cijL and cijR are the left and right centers, respectively
σijL and σijR are the standard deviation on the left side and right side, respectively, of the membership function for the jth input variable in ith rule.
The premise parameters are randomly selected around the cluster centers obtained. The membership grade $\mu_j c_i$, for the input x_j, is obtained using equation above.
The firing strength of the rules is obtained by equation below.

$$w_i(x) = \mu_{1ci}(x_1) \otimes \mu_{2ci}(x_2) \otimes \cdots \otimes \mu_{nci}(x_n)$$

where ⊗ indicates 'and' operator of the fuzzy logic.
Firing strength normalization layer
The firing strength obtained in the previous layer is normalized using equation (3)

$$\bar{w}_i(x) = \frac{w_i(x)}{\sum_{k=1}^{L} w_k(x)}$$

The consequent part of the fuzzy rule is obtained by a neural network with p_{ij} as the weight parameters.
Consequent parameter layer
This layer consists of a neural network with consequent parameters of fuzzy rules as its weight. The consequent parameters are obtained using extreme learning algorithm. The output of the layer is computed by equation below.

$$\beta_i = p_{i0} + p_{i1}x_1 + p_{i2}x_2 + \cdots + p_{in}x_n$$

where p_{ij} (j=0, 1, 2, …, n) are the consequent parameters.
Output layer
The defuzzified output of the overall network is obtained by equation below.

$$y = \sum_{i=1}^{L} \beta_i \bar{w}_i(x)$$

I. RESULT ANALYSIS

Monthly Result Analysis retail sales forecasting is performed monthly from June-2017 to June-2018. The monthly demand forecasting is also termed as long-term prediction. The performance of the fuzzy adaptive extreme learning machine is showed in table I.

Table I: Shortfall Analysis Monthwise

Month	Actual Demand	Forecasted Demand	Shortfall (in %)
JUN-17	397	395	0.503
JUL-17	1152	1149	0.260
AUG-17	2375	2334	1.726
SEP-17	632	627	0.791
OCT-17	2199	2158	1.864
NOV-17	2826	2775	1.804
DEC-17	1630	1603	1.656
JAN-18	2171	2147	1.105
FEB-18	1726	1703	1.332
MAR-18	2092	2057	1.673
APR-18	1195	1182	1.087
MAY-18	574	568	1.045
JUNE-18	553	550	0.542

VI. Conclusion

The neural network displays a satisfactory ability to solve most of difficult problems appeared in supply chain management. In addition, neural network has a strong ability to adapt and easily combines with other technologies, which can learn from each other and make up their own deficiencies. The hybrid model can solve more problems appeared in supply chain management. Accurate forecasts are crucial for successful manufacturing and can lead to considerable savings when implemented efficiently. Fuzzy set theory is also another useful tool to increase forecast efficiency and effectiveness. The ELM concept has been applied to the systems to reduce computational complexity which gives accurate models. As fuzzy adaptive extreme learning machine has good results for regression problems.

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