Predictive and Comparative Analysis on Products Demand in Supply Chain and Management

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Abstract—Retailers industry normally involve big investment as their products have many categories with different options. To increase the profit margin, retailers need to identify the right products otherwise cost and stock of their products would increase significantly. The efficient demand forecast system is a useful method to accomplish prior goals, improve customer satisfaction and reduce out of stock conditions for products. The main idea behind this study is to predict the demand of products for future and increase the sales revenue of grocery retailing industry by using two machine learning algorithms namely support vector machine (SVM) and artificial neural network (ANN). In this study, the dataset of a supermarket located in Pakistan is used which comprises of the actual demand of the past year. The results specified that SVM ensured a better-forecasted quality rather than ANN.

Keywords—Demand Forecasting, Customer Satisfaction, Sales Revenue, Support Vector Machine (SVM), Artificial Neural Network (ANN)

I. INTRODUCTION

Inventory management system plays an important role to keep tracing the inventory level orders, and sales of the business [1]. Inventory management is the procedure for monitoring the product stored in the existing retail market. A massive amount of data is generated and collected every day regarding stocked items in the inventory management system. The efficient inventory management system is the necessity to lead in the worldwide marketplace. It is often a non-trivial task to efficiently manage stocked goods because of increasing the volume of transactional data. It is very critical to analyze the underlying dependencies of the inventory items and give the insights into implementing the intelligent management systems [2].

However current inventory management systems rely on statistical analysis of the historical inventory data and they have an inadequate capability of intelligent inventory management System. The artificial neural network methods had been used to discover hidden patterns and forecasting future tendencies and behaviors in retail markets [3]. The competitive benefits carried out by neural network consist of increase sales and decrease cost price and lead to improve responsive attention of market [4]. One of the primary goals of this study is to understand the possibility and implement a comparative based analysis in order to forecast the partisan signals in the supply chain and management process by the use of different modern techniques that are not linear in nature. To the point, the study comprises on predicting the demand of the inventory cycle specifically. The most difficult part of the study is the misrepresentation of signals because it goes over the prolonged inventory cycle chain. The perfectionistic combined interactions are given by [5] and a rounded concept of inventory cycle provided by [6] is reflected by the term extended supply chain.

Furthermore, the fundamental demand of patterns for a particular product suggest that inventory might be restocked inadequate time to modify the demand of customer products. These are unpreserved products and they have a small shelf life. Furthermore, the supermarket stores facing more problems in term of very slow and inconsistency in sales for various items in stores. The modernized demand forecasting system can provide innovative opportunities to raise the performance of retail [7]. However, it remains a challenging mechanism to automate point of sales over scale system and may be a useful resource to deal with the bulk of retail records for future analysis. It is very tough for well-recognized industries wanting to compete at global level produce and sell [8].

Currently, artificial neural network (ANN) and its application is to predict and evaluate the future demand of products. Many researchers are using ANN to resolve the demand for forecasting related difficulties of Products [9]. The experimental results showing that the performance of SVM is better than the traditional statistical model as well as the traditional artificial Neural Network ANN.

II. LITERATURE REVIEW

The inventory patterns of a huge retail data and the techniques to set up the appropriate methods to evaluate the inventory management system through Support Vector Machines (SVM) and Artificial Neural Network (ANN) are explained [2]. In this paper monthly information of six different customer products shower gel, deodorant and fabric detergent, dishwashing liquid, body lotion, cooking aids from Jan 2009 to Aug 2011 (32 cases) was used to evaluate the accomplishment of the distinctive techniques. The two suggested methods ANN and SVM were used to accumulate the models considering the sample of data by using these six products to predict the demand. The results were indicating that SVM had better forecasting accuracy in term of mean absolute percentage error than ANN in every category of products.

However, another crucial discovery was the margin of a variance of mean absolute percentage error [2]. In this paper, the purpose of using the support vector machines (SVM) and recurrent neural networks (RNN) is to forecast biased demand of products and check out the bullwhip effect of a supply chain management [1]. In this research machine learning techniques are used to comparatively checking the better performance of (SVM) and (RNN) of containing two datasets, the first one dataset represents the results of the simulations of an enlarged supply chain and the second one dataset include the actual foundries data provided by (Statistics Canada). The support vector machines (SVM) and recurrent neural networks (RNN) were delivered the most better results on the foundries test set and also we can see that the tendency estimate and naive prediction showing the worst kinds of demand signal processing meanwhile they have the maximum level of error [7].

An artificial neural network to predict the fuel consumptions for the next years based on the presently available data [10]. In this project, the data of fuel filter available from 2011 to 2013 already consumed in a large company. The author considers the base year data of 2011 based on 12 months to predicting the next year 2012 [3]. The data of the year 2012 is available but is not considered for forecasting data, but only considered as a target data. The anticipated procedure can be deliberated as a successful decision supporting tool in demand forecasting. These methods have the capability to forecasting precise future results [10].

An effect is known as bullwhip that is related to the request unpredictability intensification to distributors from retailers [11]. Another study considered the effect of exponential levelling prediction over the effect known as bullwhip effect by the retailer [12]. Many boundaries can be astounded by the application of neural networks in demand forecasting. Mathematically proved neural networks to be the common estimation of functions [13]. The prediction of the short term and long term demand by the use of ANN for the electric load [14].

III. THEORETICAL FOUNDATION

The prediction of demand refers to the anticipation of the demand for an individual product based on its previous historical sales data. Based on competition and globalization, the anticipation of sales data plays a vital and prominent part in a decision support system [2]. Demand forecasting is particularly a very complex problem because many internal and external environmental factors are involved specifically for the textile and fashion industry.

Due to this fact, how to develop an efficient demand prediction model is becoming a very interesting topic in the research community. The stocking decisions have been improved by a few retailers by gathering the current information of market and repeat their prediction in different stages. Over-stocking and under-stocking conditions can be minimized by an efficient demand prediction method[10].

ANN with Backpropagation (BP) learning algorithm is widely used in solving various classification and forecasting problems.

A. *Artificial Neural Network:*

The architecture of an artificial neural network technique is to simulate the human brain and analyze the processing of information using ANN. The most commonly used techniques are feedforward and error back propagation while using this network the single essentials of neurons that are systemized into different layers in a specific way that indicating given output signals from the neurons in such that all the neurons that are passed from next layers.

Therefore, the abundance flow of neurons activates and going in one direction only on a layer by layer. There is two smallest number of layers that are the input layer and output layer, the additional layer, is called a hidden layer that is between the input and output layer. The idea behind this hidden layer is to increase the computational power of the neural network.

Figure 1 is showing a sigmoidal unit with the 3 inputs and one output and also bias on weight vector so each of the inputs can be the output of some other sigmoidal unit and the output units would be further sigmoidal units of another input. Note that each output of the weight vector corresponds to every element of the input vector as a result, the summation of the individual pairs is equivalent to the dot product, as mentioned within the previous sections.

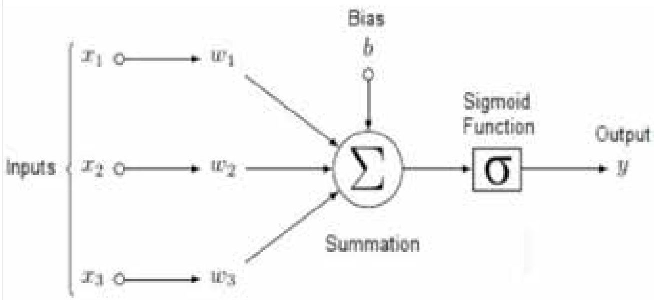

Fig. (1). Artificial Neural Network.

a. Feedback ANN:

Feedback ANN is a type of artificial Neural network ANN in which the output is going back into the network to achieve the high-quality-advanced outcomes. Feedback ANNs are used by the Internal system error corrections.

b. Feed Forward ANN:

Feedforward neural network is a very simple neural network that comprises an input layer and also an output layer with one or further layers of neurons. The output of this network is based on the connected neurons that behave accordingly in the group of neurons. The main benefit of this network is that it learns to evaluate and recognize input patterns.

B. Support Vector Machine:

Support vector machines SVMs are a recent type of regular function of approximations which can be primarily based to reduce the minimization of risk on structural environments precept from statistical studying concept instead of the realistic minimization of risk which is the based on linear regression and neural network [15]. The main idea of SVM is to reduce the structural minimization of error and overcome mistakes on an unseen and randomly decided on check instance as opposed to Neural Network (NN) and multiple linear regression (MLR). A complexity parameter permits the adjustment of the number of errors versus the model difficulty and uncorrelated kernels like RBF kernel, can be used to allow non-linear mapping into high dimensional space.

a) Kernel Function:

The main fundamental of making nonlinear SVMs is to map the x input vector into z vector of multi-dimensional feature space (i.e. z=phi(x)), where phi is a mapping function. The component xi of an input vector x spanned an input space x and the component phi (i) of x of vector z spanned a feature space z. Due to applying such a mapping function, it could be estimated that the learning algorithm is much more capable of separating images in space z. Basically, in this approach, we could face two basic problems: The selection of a mapping function phi(x) , the second one is based on the phenomenon known as ”curse of dimensionality”.

b) Forecasting System Framework based on SVM:

Accurate forecasting is essential to get accurate decision making. Time series prediction models are totally established on the estimated values that the upcoming value of a variable is connected to their own previous historical values. The main motive of time series prediction is to establish the patterns in previous data and then assign the patterns in the future or upcoming values. Though, some values are influenced by upcoming values of more than one factor. For instance, the demand for farm product can follow past values, but other factors could also be influenced at the same time for example holidays, change in weather, consumer preferences and so on. So due to this factor, it will not be enough or effective to use time-series prediction in predicting the demand for perishable farm products. Furthermore, mostly forecasting methods were used previously to establish multiple models in the light of original data which can contain some void information or data.

Therefore, an intelligent forecasting system is proposed to improve the models. The proposed forecasting system model works in two different ways. The first way is to practice the historical sales data, which contains smoothing (to avoid singular values) and normalization processing (to eliminate data overflow) of the data. The second way is to make a course of dynamic information for instance sales prices, cost prices, profit gross, date, related to historical data. After processing the original data, the training sets are formed.

After that, the training samples that we get after applying some data processing are passed through the SVM model to train the model and learnt for regulating the constraints to the finest values. The model will then be able to make decisions after the machine finishes the learning process. It is proven that the overall outcome of this demand prediction for consumer products can be enhanced with greater accuracy by considering some effect factors such as sales price, cost prices, date, profit margin etc.

IV. STRUCTURED METHODOLOGY

This section illustrated the structured methodology applied in order to find the most optimal and desired results of the experiment. The roadmap to be followed in this study is described below.

The initial stage of this methodology is to exploit the data which is used throughout the study for analysis followed by the model initialization. The second step is based on the application of two different experiments that run simultaneously, one for an artificial neural network and one for the support vector regression. In the same step, the performance analysis is performed on both sides which is followed by the execution of the artificial neural network (ANN) and support vector regression (SVR). The results obtained from the determination of both ANN and SVR are then compared to find the comparative results of this study.

V. EXPERIMENTAL SETUP

A. Data Manipulation

The data set used throughout this study based on the previous months of retail sales data of a supermarket. The data set used in this study is depicted in table 1. This overall data is computed in two different forms called normalization and division.

Table 1. A Snapshot of a Daily Sale Products

Code	Sales	Cost	Profit	Date	Demand
483	160	136	24	11-9-17	10
1509	215	182.8	32.2	11-9-17	12
3366	207	176	31	11-9-17	21
4116	170	144.5	25.5	11-9-17	23
5454	155	131.8	23.2	11-9-17	15

a. Data Normalization:

The total data set was normalized and scaled in order to make things easier for the network. Normalization has been done using:

$$X_{new} = (X - X_{min})/(X_{max} - X_{min})$$

Where X_{new} denotes the scaled data point, X is the actual data point, X_{min} and max are the minimum and maximum values in the data set, respectively. This is done in order to guarantee that the smallest value in the data set is scaled to 0 and that the largest value is scaled to 1.

Table 2. Distribution of the Data Set

Data Set	Distribution	Total
Training Set	7000*7	49000
Validation Set	2000*7	14000
Testing Set	4000*7	28000

b) Data Division

The sales data obtained from a supermarket which comprised of approximately 95000 data points from the 1st of January 2017 to the 35th of December 2017.

To minimize the effects of the missing data points, the missing data points have been detached from the data set. In the result, the remaining data shrank to 90000. To apply the cross-validation technique, the data has been divided into three data sets which are independent of each other named validation set, training set, and testing set. Table 2 shows the distribution and sum of the data set.

B. Model Initialization:

Table 3. Results to Find Out the Number of Models.

Input Features	Training Errors
2	1.68649
3	1.67655
4	1.65662
5	1.68556
6	1.63215
7	1.60212

The issues related to the number of model inputs are discussed in this section. A very brief investigation is done from ANN perspective. The debugging technique is applied in order to find the best model for 'n' number of inputs. At the initial stage, only two inputs are given to the model, followed by three, four, five and six inputs. The minimum training error is found in the network with five inputs and therefore this model is adopted. The results obtained from the procedure of model input development by applying the debugging technique is depicted in table 3.

To find the non-biased comparison between ANNs and SVMs, the same number of inputs for the model was used for the Support Vector Regression.

VI. EXPERIMENTAL RESULTS AND ANALYSIS

The neural network is applied to the above-discussed data set. Figure 3 depicts the model and mapping function of the predictive analysis over ANN. The model is trained on training observations ranging from Jan 1, 2017 till Nov 30, 2017. The testing data observations from the month December is given to that model and the model predicted the continuous values. Figure 2 Shows the comparison between training and testing errors and the overall performance of the model. The accuracy of the model is 93% because the model produces 7% error in the testing phase as can be seen in figure 3.

The support vector machine is applied for the purpose of regression approximation. Figure 4 depicts the model and the mapping function of SVM. The accuracy of the SVM model is 97% and it is failed to predict 3% observations in the data set. The main objective of this study is to do a comparative analysis of the results produced by ANN and SVM. It is evident from the analysis that SVM has a better ability to predict the upcoming event in terms of its accuracy. Figure 4 implies that SVM is a better approximation tool for this study.

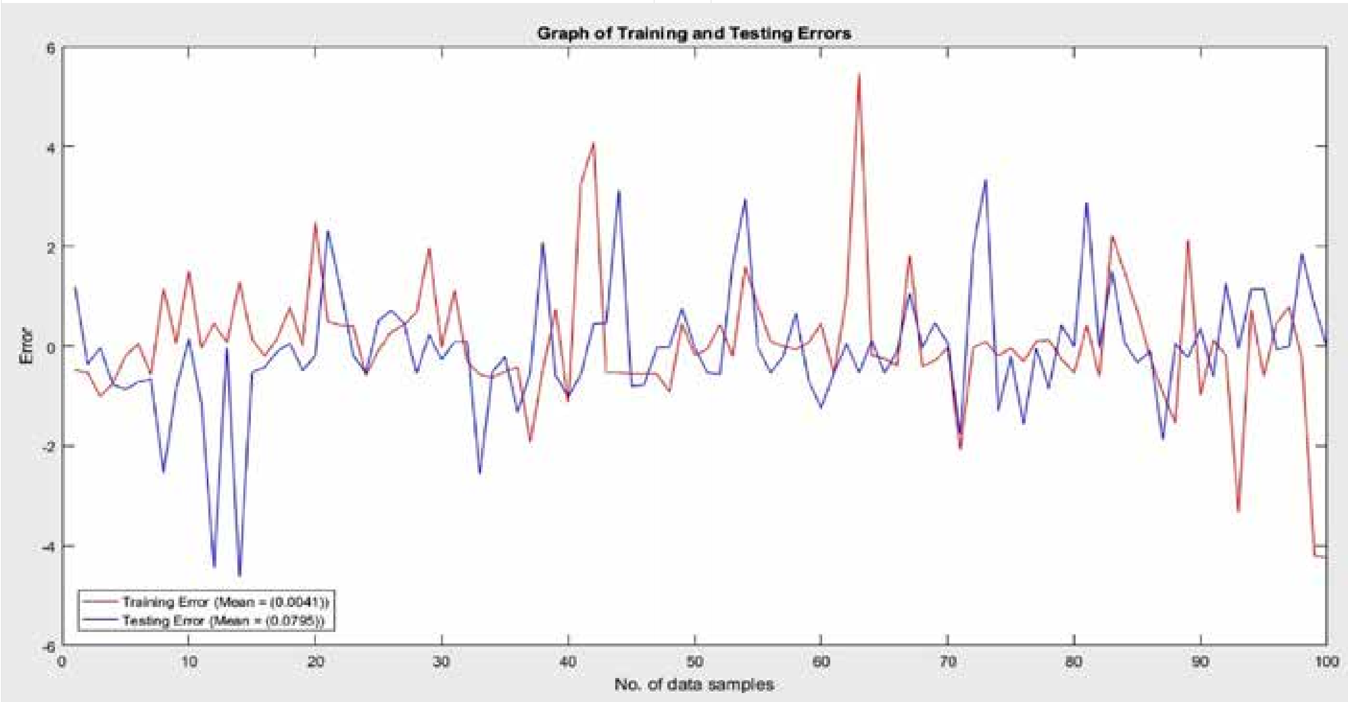

Fig. (2). Comparison Between Training and Testing Errors.

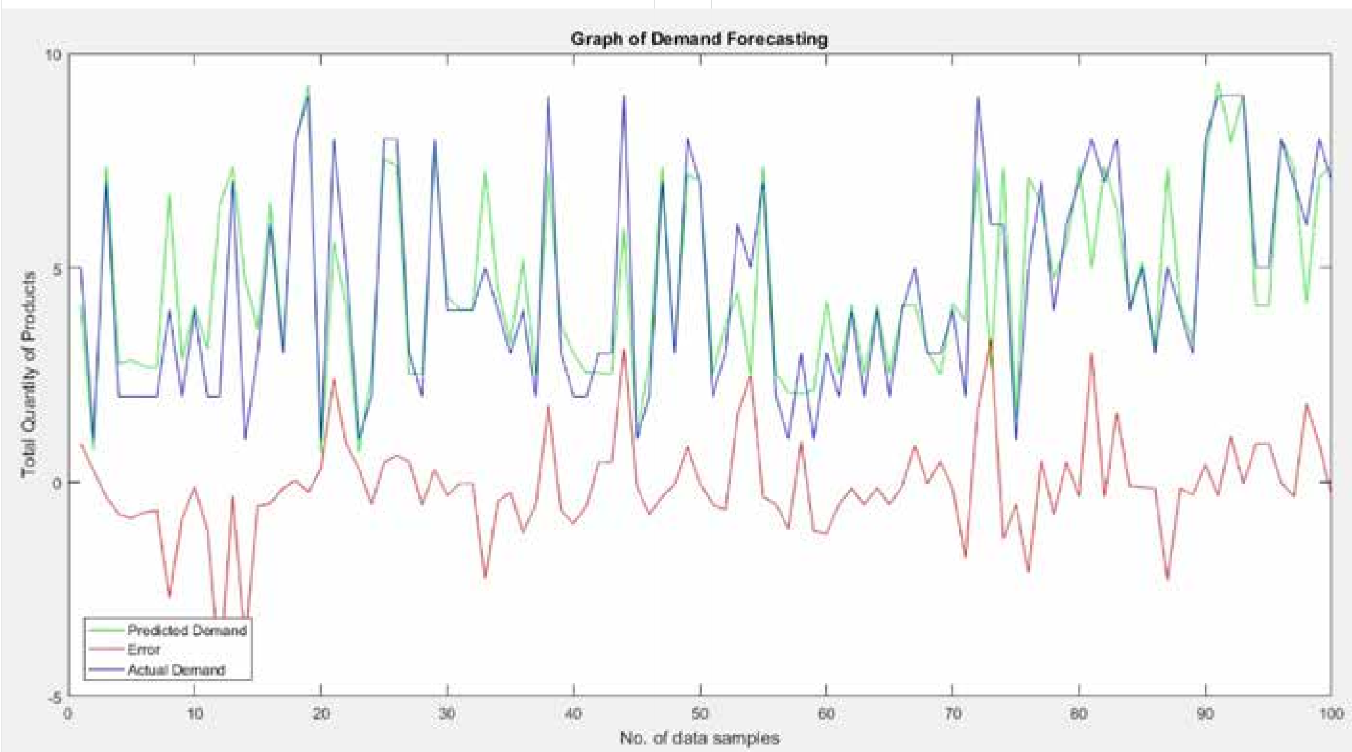

Fig. (3). The mapping function of ANN.

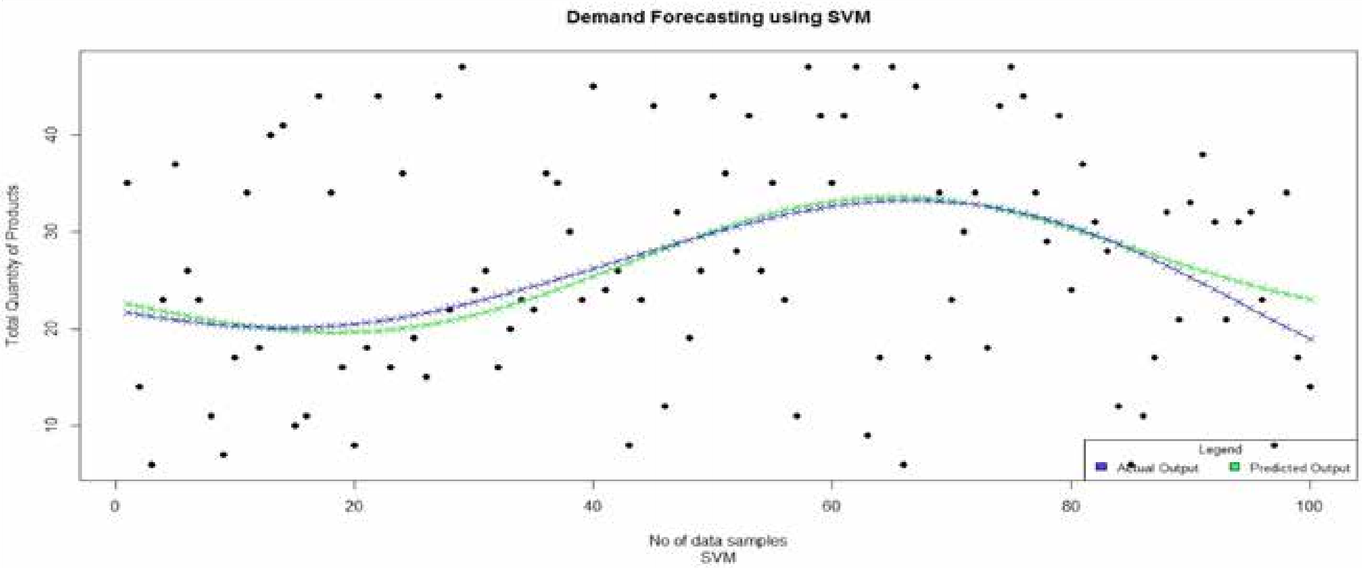

Fig. (4). The mapping function of SVM

VII. CONCLUSION AND FUTURE WORK

In this study, two machine learning algorithms have been applied for the predictive regression analysis which is an artificial neural network (ANN) and supports vector machine (SVM). The primary objective of this study is to anticipate the demand of a specific product in the upcoming month with the help of previous sales data of a supermarket in Pakistan ranging from Jan 1, 2017 to Nov 30, 2017. The results are beneficial for different supermarket stakeholders in order to manage to inventory stock level more efficiently. The methodology adopted was to process two experiments in parallel, one for each ANN and SVM.

The comparative analysis is made on the results from ANN and SVM and comes up with the best model that predicts the future demand for a product with more precision. According to figure 3-4 , SVM produces better accuracy and precision in comparison with ANN. Future research could be based to predict the reasons for the increase and decrease in demand for a product by introducing the new features that are related to customer satisfaction i.e. customer reviews on that product.

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