KU LEUVEN

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ASSIGNMENT 1: Paper Discussion

Summary

Good inventory management is key to successfully running a business. Not having a systematic approach to sourcing, storing, and selling inventory can result in blown-out costs, loss of profits, poor customer service, and even outright business failure. There are currently many techniques and practices for tracking inventory in place, each with their pros and cons. The selected article presents the reader with a new approach to eliminate waste in the supply chain. By using a multilayer feed-forward neural network with backpropagation, businesses will be able to "minimize the supply/demand mismatch and its associated costs and consequently increase profit margins". This approach to inventory management is different from conventional methods as it detects interdependencies that are hard to detect with normal analytical tools. The proposed system performs forecasting analysis, minimizes error, and assists in the rapid changes in customer demand.

Nature of the Article

To fully grasp the extent of the article, one has to be familiar with some of the basic concepts laid out within the article. Hence the history of inventory management, artificial neural networks, and time series forecasting will be briefly discussed below.

Even though the practice of buying and selling things has been around for centuries, formal inventory management as it is known today has not. The concept of inventory management only started to develop in the period before the Industrial Revolution. During these times, merchants and shopkeepers wrote down purchases and kept track of how many units they had sold at the day's end. Based on this information and intuition, they had an idea of the number of products that they would have to order for future use.

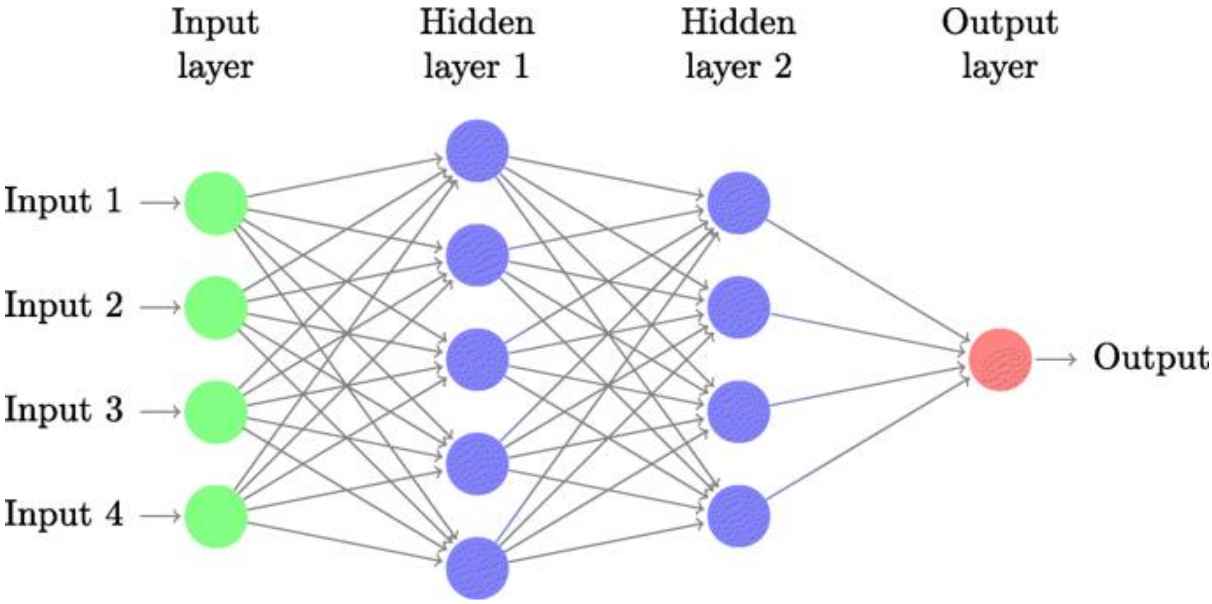
As the Industrial Revolution came around, the focus shifted to mass production and efficiency. Businesses blew up in size, necessitating better inventory management. This sparked inventions such as Herman Hollerith's by machines readable punch card. In the 1930s a Harvard University team utilized this punch card to create the first modern check-out system. Customers would fill out the punch cards with a combination of punches that corresponded with specific catalog items. The punch cards were then fed to and read by a computer, which in turn would pass on this information to the storeroom. Because of this process, computers were able to handle billing and manage inventory. The system was not popular at the time because of the high costs and the long lead time associated with it.

Although the punch card system resembles the current billing system, the real forerunner of the barcode system was created in the late 1940s and early 1950s. It utilized ultraviolet light-sensitive ink combined with a reader. Because technology was not on par with the idea at the time, the system never got implemented. In the 1960s, a group of retailers got together and revived the system, introducing the modern barcode to the world. There were several types of competing barcodes until they were standardized with the Universal Product Code (UPC) around the 1970s.

In the 1980s and 1990s, computing technology improved and advanced. Performant personal computers became commonplace. A few years later, during the mid to late 1990s, businesses began writing code and implementing software, which allowed computers to store information about scanned products. This marked the beginning of modern inventory management.

A lot of businesses today use Radio Frequency Identification (RFID) to rapidly collect information about products in warehouses, factories, and stores. Microchips transmit product information, such as type of product, manufacturer, and serial number, to a nearby scanner. It has several advantages over the barcode system, the most notable being that scanners are able to read the RFID tag without it being in direct line of sight.

Of course, businesses are nothing with the collected product information if they do not possess the proper software to store and process it. As Artificial Intelligence (AI) grows in popularity, so does its application in diverse fields. One part of AI which has received a lot of attention in the past few years is Artificial Neural Networks (ANN). ANN are biologically inspired computational networks that learn by example, a technique that is referred to as deep learning. Deep learning is a subset of machine learning in AI that has networks capable of learning unsupervised from data that is unstructured or unlabeled. This is possible because of their structure; an ANN consists of an input and output that are connected by one or more hidden layers. These hidden layers transform the input into the output. Each layer is made up of several nodes, called artificial neurons. The nodes of neighboring layers are interconnected so that they can process and transmit signals to other neurons, similar to the synapses in a human brain.



The basic operation of an ANN can be explained through a simple thought experiment. Let us say somebody wants to design an ANN that recognizes images of dogs. After writing the necessary code (i.e. the neural network), the creator presents the ANN with several images, manually labeled as 'dog' or 'not a dog'. The images act as the input, whereas the labels function as the output. By comparing the input with the output, the ANN will generate identifying characteristics, similar but yet different to what humans do by looking at the fur, tail, and snout. It does this by weighting the connections between nodes located in different hidden layers. As a result, groups of nodes will be responsible for analyzing a certain characteristic. After processing several examples, the network will have figured out which characteristics are specific to dogs and be able to successfully detect dogs in new images.

Surprisingly, ANN have been around for quite some time, since the 1940s to be exact. The reason they only recently started gaining popularity is because of a technique called 'backpropagation'. Backpropagation allows the user to directly interact with an ANN. When the network's output layer does not match the expected outcome, the creator can provide it with the desired output. As a result, the network will automatically adjust its weights in the hidden layers to correct the mistake. The more learning examples the network receives, resulting in an increased number of backpropagation iterations, the more accurate it will become.

Time series forecasting is another important aspect of machine learning. Whenever observations are recorded at constant time intervals, it is referred to as time-series data. In contrast to other predictive models, time-series forecasting uses patterns and reoccurring trends from previous periods to predict what will happen in the next period. A time-series forecast can give an estimate of the demand or figure out how long a certain trend will continue.

Now, one can imagine what would happen if ANN are used in combination with time-series data. The selected article briefly discusses the result of this mashup and its specific application to inventory management. It starts with a short introduction, followed by a literature review. The literature review gives a summary of the sources used for the study outlined in the article. The article is about basic research that builds upon, and therefore is an extension of, previously conducted research. The researchers then write about the methods and procedures which comprise the study. The methodology covers the programming and implementation of an algorithm, research design, data collection, training, and testing. The obtained results are subsequently analyzed and discussed in the analysis section. The authors wrap up their article with a conclusion, in which they state their findings and the benefits of their system.

The ANN programmed for the study is trained using a dataset obtained from Kaggle, a data science community. The dataset includes past sale records of 45 Walmart stores, located in various areas and each containing different departments. The information is gathered on a weekly basis. The training data is the data accumulated from January 7, 2011, until November 26, 2012. Even though it is not explicitly mentioned, in order to get the most out of two years of data, the researchers likely used the following approach to construct their model:

- The data of weeks 1 through 52 are fed to the algorithm as input.
- Based on this information, the model is asked to predict the data for the next three months, i.e. weeks 53 through 65.
- The actual data for weeks 53 through 65 is compared with the calculated output and the difference used to backpropagate through the network, causing it to adjust the weights in its hidden layers.
- The data of the first week is purged from the input and the data of week 53 is added to the input, moving each data point up one. Thus, the data from weeks 2 to 53 are now the new input data, while weeks 54 through 66 are the new output.
- This process is repeated until the output includes the last data point, after which the network is iterated with the same data until it is stable.

After training, the same dataset is used to test and evaluate the accuracy of the constructed model. The results of the test sets are analyzed, discussed, and compared to the performance of today's supply chain network. "The accuracy achieved in this study by implementing an AI system which uses the ANN algorithm is about 75%-80% which is two to three percent higher than the average accuracy". The pros and cons of the proposed approach are also presented in the article.

The study described in the article suggests that utilizing an ANN to forecast sales based on time series data is beneficial to businesses. By having a more accurate prediction of future sales, businesses can more accurately manage their inventories, for example by comparing forecasted sales in the future with their current inventory and ordering the necessary number of products on time. This way they will be able to increase profit margins, which is essentially the motivation behind the writing of the selected article.

Opinion

Overall, I think that the article is clear and to the point. Once I had conducted some research online and read the article several times, it was not too difficult to understand. The conclusion was well written and nicely summed up the most important aspects of the study. I have, however, two remarks.

First of all, the article does not clarify how data specificity which accompanies an ANN acts as a double-edged sword. In such a manner, a network trained using data from Walmart will not be able to accurately forecast sales for another chain such as Best Buy. Both Walmart and Best Buy are, however, able to use the same with formulae hardcoded program to manage their inventories. Despite not being universally transferable without training data, an ANN will yield more accurate results than a traditional program, because the training data is specific to a certain company and it can detect interdependencies not taken into account by formulae.

This brings me to my next remark; even though the article points out that using an ANN to manage a supply chain can be a time-consuming process, it does not directly address the most prominent weakness: the availability of data. A start-up company with a large starting capital does not have specific data to work with. They would either have to fabricate data based on an educated guess or use the data of a similar business. On top of that, as mentioned before, the more data available, the more accurate the output of the ANN algorithm.

The article accurately analyzes the application of near advanced AI networks in inventory management. The study conducted banks on earlier research and opens up opportunities to further investigate this application. It shows how advancements in computational technology can facilitate inventory management. The results look promising, especially for businesses with huge capital inventory investments. These companies are looking for the latest advances in inventory management as small improvements can lead to huge savings.

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Inventory management and cost reduction of supply chain processes using AI based time-series forecasting and ANN modeling

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Abstract

Reducing waste, and therefore cost, within a supply chain can be a very challenging process due to the large number of variables involved. One of the biggest wastes that are usually present in a supply chain are unnecessarily high inventory costs and shortage costs which are caused by errors in demand forecasting. A high variance between the forecasted demand and the actual demand results in costs that could have been avoided. To eliminate that waste, we developed a model that utilizes artificial neural network to accurately forecast the demand. The model performs forecasting analysis based on multilayer feed-forward neural network with backpropagation. The use of machine learning can assist with the rapid changes in customer demand. Our holistic solution will minimize the supply/demand mismatch and its associated costs and consequently increase profit margins

Peer-review under responsibility of the scientific committee of the Flexible Automation and Intelligent Manufacturing 2019 (FAIM 2019)

Keywords: ANN;Supply chain management; Time-series Forecasting; Multilayer Feed-Forward Neural Network; Back propagation; Optimization; process enhancement; R-Studio; Predictive Neural Network

Peer-review under responsibility of the scientific committee of the Flexible Automation and Intelligent Manufacturing 2019 (FAIM 2019)
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1. Introduction

Manufacturing and distribution companies with their various supply chain networks often operate at below maximum potentials and lose out on millions of dollars annually. Thus, utilizing the ideal software intelligence in today's time can help increase the performance of these supply chain networks to their max potential. One way to achieve this is by implementing machine learning into Enterprise Resource Planning (ERP) systems. ERP software integrates various functions such as goods, employees and customers into one complete system to streamline processes and information across the entire organization. Machine learning has many tools and the one being used in our system is Artificial Neural Networks, considered as "nonlinear statistical data modeling tools where the complex relationships between inputs and outputs are modeled or patterns are found." (Techopedia, 2018). This marriage of systems can lead to optimizations in current demand, demand in the next 3 months, the current warehouse values purchase pricing and transport cost.

2. Literature Review

Literature search is conducted to compare various methodologies and to provide a background to this study. A summary of the literature review, topic, method, strengths and weaknesses of these sources used for this study is given in Table 1, categorized by the method used and strength and weakness of each paper.

Table 1: literature review summary

Reference	Topic	Method	Strength	Weakness
Jad Farhata, Michel Owayjan	ERP Neural Network Inventory Control	Embedding ANN algorithm with ERP	Increased forecasting accuracy	Systematic Input and religious tracking required
Sven F. Crone	Artificial Neural Networks for Time Series Prediction - a novel Approach to Inventory Management using Asymmetric Cost Functions	Seasonal cost and inventory forecasting using ANN forecasting techniques and ARIMA models	Seasonal trends taken into account, Increased forecasting accuracy	Considers only under estimation and not over estimation of inventory
Bo Xing, Wen-Jing Gao, Kimberly Battle, Tshilidzi Marwala, Fulufhelo V. Nelwamondo	Artificial Intelligence In Reverse Supply Chain Management: The State Of Art	Reverse engineering using AI algorithms	Model able to assist practitioners decision	Only a certain AI algorithms tested.
Tereza Šustrová	A Suitable Artificial Intelligence Model for Inventory Level Optimization	Using AI forecasting to determine Quantity to order	Takes into account all aspects required to make an order including demand, forecast, price and seasonality	One single over the top bad or good season could topple the model
Erik Fosser, Ole Henrik Leister, Carl Erik Moe, Mike Newman	ERP systems and competitive advantage: some initial results	Link between ERP systems and competitive advantage	ERP system can be used to feed data warehouse and gain competitive advantage	Changing from SAP to ERP would be difficult due the high associated costs
Andrew Harvey, Ralph D. Snyder	Structural time series models in inventory control	Using statistical models in inventory management	Models are used for deriving formulae for estimating the mean and variance of the lead time demand distribution under both constant and stochastic time assumptions.	Kalman filtering can be used for only linear state transitions
Aburto, L., Weber, R.	Improved supply chain management based on hybrid demand forecasts. Applied Soft Computing.	Hybrid Forecasting Models	Detailed instructions shown to improve supply chain management systems using ARIMA type process. Backpropagation is used to adjust network's weights.	Learning process can lead to an overfitted model, thus losing its ability to generalize.
G. Dorffner	Neural Networks for Time Series Processing	Forecasting technique using ARIMA model	Ability to approximate arbitrary nonlinear functions. Classical pattern recognition, detecting systematic patterns in an array of measurements which do not change in time.	Model only has short term use. Nonlinear functions cannot be used for larger problems.
Mohamed T. Kotb, Moutaz Haddara, and Yehia T. Kotb	Back-Propagation Artificial Neural Network for ERP Adoption Cost Estimation	Neural network model	Cost estimation without defining the function points. This model can be extended and can be applied in various environments	Model is limited in data processing.

This summary indicates that although ANN model has some weaknesses but comparatively is more effective modelling method to be implemented in time series forecasting.

3. Methodology

The prediction technique used is Artificial Neural Network (ANN) modeling as it is capable of handling data with high volatility more accurately. ANN thus overcomes the shortcomings of traditional forecasting models. The algorithm and implementation of this approach is presented in the following sections.

3.1. Algorithm

To use Artificial Neural Network (ANN) to accurately forecast the future demand, we needed to develop an algorithm. The following steps are used to develop our proposed model.

Step 1: Determine the neural network architecture to be used to design the system. Determine the number of input nodes, hidden nodes, hidden layers and output nodes.

Step 2: Data cleaning

• Remove NAs, which causes error in the model

• Eliminate unnecessary columns and add columns based on the time series forecasting model- linear trend, quadratic trend

• Normalize the data after all information has been filtered

• Divide dataset in two halves for training (2010-2011, 2011-2012) and testing (2012-2013)

Step 3: Create a training sample with feed-forward network and resilient backpropagation (RPROP) with weight backtracking

• Use Logistics function as the activation function

• Set the learning rate

• Calculate the actual

output Step 4: Testing

the dataset

• Validate the result by comparing the prediction with actual data

(2013) Step 5: Minimize the error

• Feed the difference between true and predicted value into the system (backward pass)

• Update weights and bias values

Upon completing the application via above steps a mode was generated that minimizes the error in the demand forecast. The details of the modules is presented in the following sections.

3.2. Multilayer Feed-Forward Neural Network with Back-propagation

The type of neural network used in the proposed system is feedforward network wherein information moves only in one-direction, which is from input layer to output layer as shown in Figure 1. The input units or computational units pass through multiple hidden layers which are stacked between the input and output layer. All three layers are interconnected. Initially, random weight and bias values are assigned to the data points. The predicted output is compared with the actual data to calculate the error.

Supervised learning technique is used to design this system. In this technique network is trained with a dataset with defined output for every input neuron. The weights are then adjusted to get the observed value closest to the true value which is achieved by the method of backpropagation. Backpropagation refers to propagating the error back to the network.

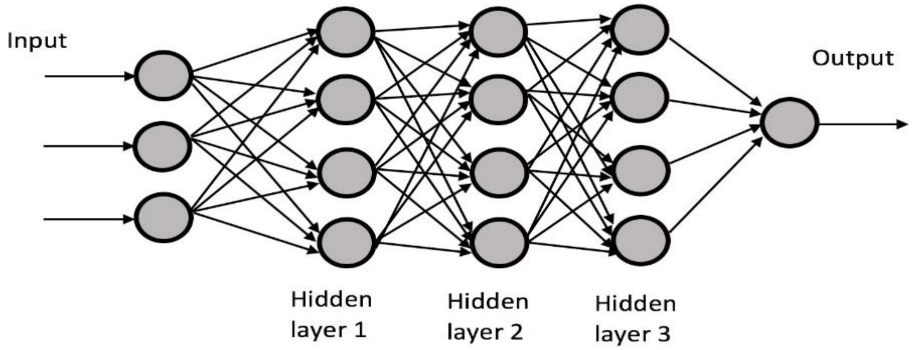

Figure 1: Sample feed forward and back propagation neural network with input nodes, hidden nodes, hidden layers and output nodes

The weights are then adjusted to get the observed value closest to the true value which is achieved by the method of backpropagation. Backpropagation refers to propagating the error back to the network. Weight and bias values can be updated using this feedback. End goal is to keep changing the weight and bias until minimum error value is achieved.

3.3. Research Design

The primary goal of this investigation is to develop a new forecasting method that performs more robust thus make the supply chain more efficient. The ANN algorithm executes at the most evident level producting promising results as outlined in the proceeding sections.

3.4. Data Collection

The dataset used here is obtained from Kaggle (give reference number). This dataset represents information about Walmart. The dataset includes past sales of 45 Walmart stores arranged in various areas, wherein each store contains different departments. The information is gathered week by week for various kind and size of Walmart stores.

The week after week deals incorporate the limited time markdowns which go before the occasions consistently. Four biggest occasions incorporate Super Bowl, Labor Day, Thanksgiving and Christmas. Weeks including such occasions have five times more weightage than the standard weeks.

3.5.1. Training

The training dataset is historical data for 45 Walmart stores located in different regions. Each store has 8 departments. The train data covers the time from January 7, 2011 till November 26,2012 (01/07/2011 to 10/26/2012). It comprises of various fields as:

• Store - The store number

• Dept - The department number

• Date - The precise date of the recorded Sales

• Actual Data - Sales for the given department in the given store

• Linear Trend - Linear time series demand forecast

• Quadratic Trend - Quadratic time series demand forecast

• Actual % of trend - Trend evaluation in percentage

The training sets were used to construct the model and using similar data sets to test the model.

3.5.2. Test

The Data set used for testing is similar to the training sets, but it only excludes the Actual Sales Feature. The dataset ranges from November 2, 2011 till June 26, 2013 (11/02/12 to 7/26/13). The analysis was conducted by constructing the model via training first. The accuracy of the model was evaluated via test sets.

4. Analysis

4.1. Application of Methods

In this section we will discuss the various methods used in our approach for a desired result. As discussed above, we have mainly used two platforms for the deployment of our process. Excel to process and assemble our dataset as an input; and R Studio for running the code and testing the forecasting results obtained.

4.1.1. Excel

Initially, the raw dataset obtained was incomplete comprising of only store number, department, date of sale, and actual sale as shown in Table 2. To compute results, TREND function in EXCEL was used. Two Types of trends were identified as Linear Trend and Quadratic Seasonal Trends as shown in Table 2 as:

• Linear Trend: Linear time series demand forecast

• Quadratic Trend: Quadratic time series demand forecast

Table 2: Screenshot of dataset in MS Excel

Store	Dept	Date	Linear_Trend	Quadratic_Trend	Actual_Data
1	1	1/7/11	15513.35454	14626.09545	15984.24
1	2	1/7/11	15513.35454	14626.09545	43202.29
1	3	1/7/11	15513.35454	14626.09545	15808.15
1	4	1/7/11	15513.35454	14626.09545	37947.8
1	5	1/7/11	15513.35454	14626.09545	22699.69

We added trends in the datasets to increase number of inputs in the hidden layer of the neural network, to elevate the results and obtain a more accurate and realistic response. Also, utilizing “lookups “ and “pivot” tables in Excel to clean the dataset by removing null values and organizing the large entry list. The filtered dataset was used in R studio as input.

4.1.2. R Studio (Packages)

The following packages are used to analyze data in R studio. The Screenshot of the output from R-Studio is shown in figure 3.

Tidyverse: A collection of R packages designed for data science.

Neuralnet: Neural net package is used to train neural networks using backpropagation, resilient backpropagation (RPROP) with or without weight backtracking. This function allows flexible settings through the choice of error and activation function and calculation of generalized weights.

Caret: It is a set of functions that attempt to streamline the process for creating predictive models.

CaTools: Contains several basic utility functions including: moving (rolling, running) window statistic functions, base64 encoder/decoder, round-off error free sum etc.

Amelia: Uses a Bootstrap+EM algorithm to insert missing values from a dataset and produces multiple output datasets for analysis. The above listed packages were used to filter, edit, and graph the data as shown in Figure 2.

4.2. Result Analysis

After analyzing the results obtained from the R model, a neural network schematic comprising of three hidden layers and a total of six hidden nodes was generated as shown in Figure 2. Every layer holding an equal weightage of 1 in this network.

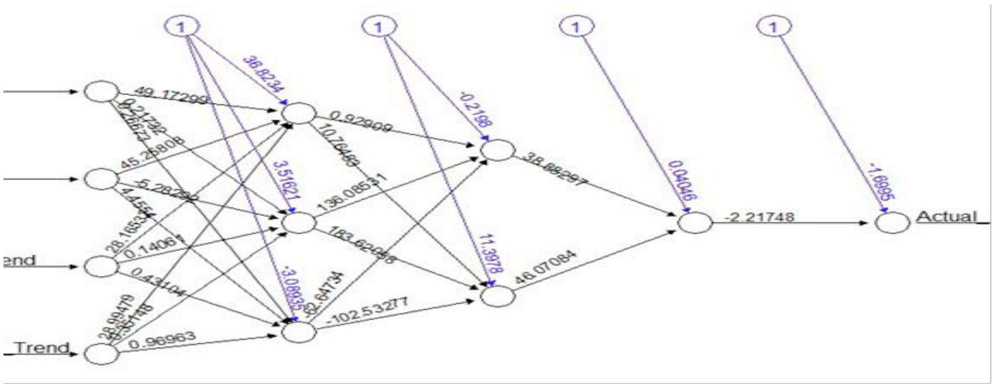

Figure 2: Screenshot of the output from R-Studio

All the predicted sale figures show linear characteristics compared to the erratically distributed original sale data as shown in figure 3. The black lines show the connection between each layer and the weights on each connection, while the blue lines show the biased terms added in each step.

By visually inspecting the plot generated by R Studio in Figure 3, we can conclude that the predictions made by the neural networks are more concentrated around the fitted line with certain errors away from the line. A perfect alignment around the line would indicate zero error and thus an ideal prediction.

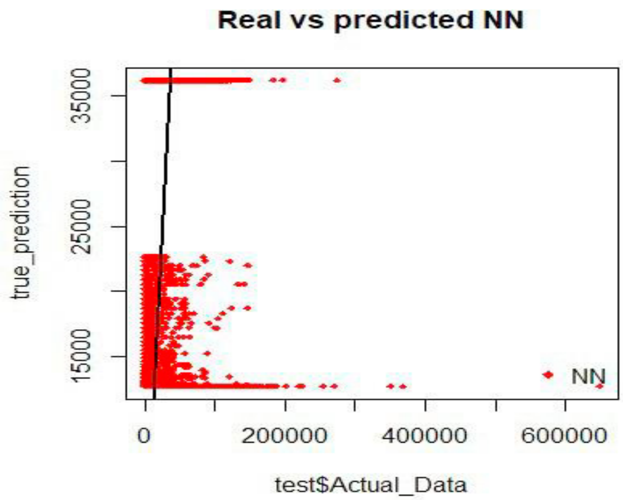

Figure 3: Screenshot of the graph from R-Studio

The forecasting accuracy and performance achieved is around 70-80% higher than the average performance of most supply chain networks worldwide.

4.3. Strengths and Weaknesses

The pros and cons of the proposed approach is presented in Table 3. ANN Models can be applied to non-linear complex problems and can make predictions by inferencing hidden relationships. The models are also a good predictor when high variability and non-constant-variance is present in the data sets. It should be noted that ANN-based models generate better results when input /output relationship is simple.

Table 3. Pros and cons of the proposed approach

Strengths	Weaknesses
ANN model handles non-linear and complex problems	If there are too many hidden nodes, the model might produce inferior results
They are capable of inferring the hidden relationships and make predictions	ANN's are best applied to problems where input and output data are fairly simple. With large dataset, the network topology can become too complex and difficult to interpret
Such models handle heteroskedasticity; data with non- constant variance and high volatility in a better way	It can be a time-consuming process

5. Conclusion

The goal of this study was to improve the overall performance and efficiency of the supply chain management, and this has been achieved by using the Artificial Neural Network algorithm. The average performance for the supply chain network is about 72%, the accuracy achieved in this study by implementing an AI system which uses the ANN algorithm is about 75%-80% which is two to three percent higher than the average accuracy, hence improves the overall performance and efficiency of the supply chain network. This model improves the forecasting analysis and gives a better prediction of future sales.

The overall improved efficiency of the supply chain networks also results in various other benefits. It reduces the overall operational costs which includes storage and transportation costs. This eventually improves the supply chain surplus.

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