Supply Chain Forecasting Using Neuro Fuzzy Expert Systems

Ranu Khabiya[1], Prof. Sanmati Kumar Jain[2]
[1]Dept of CSE
[2]Assistant Professor and HOD, Dept of CSE
[1, 2] VITM, Indore

Abstract- *Recently, there has been a substantial increase in the demand for pharmaceutical products and pharmaceuticals as a result of the ongoing COVID-19 situation. There have been multiple recorded cases where a significant shortage of medication has resulted in the death of individuals. Therefore, it is crucial to adopt a comprehensive strategy to demand forecasting for the pharmaceutical supply chain. Recently, soft computing techniques are being used widely for demand forecasting due to relatively higher accuracy compared to conventional statistical techniques. This study introduces a hybrid model called the wavelet transform-adaptive neural fuzzy inference system (DWT-ANFIS) for predicting pharmaceutical product forecasts. The Discrete Wavelet Transform (DWT) has been employed as a tool for data cleansing and optimization, while the Adaptive Neuro-Fuzzy Inference System (ANFIS) has been utilized for forecasting purposes. The assessment of the suggested work was conducted using the mean absolute percentage error, regression analysis, and system iterations. Evidence demonstrates that the suggested approach surpasses the current system in terms of the Mean Absolute Percentage Error (MAPE).*

Keywords- Demand Forecasting, Machine Learning, ANFIS, MAPE, Accuracy.

I. INTRODUCTION

As a result of the ongoing COVID-19 situation, the pharmaceutical industry has faced significant strain in terms of distributing medicinal items. There have been other cases where there was a shortage of life-saving drugs and essential supplies, leading to- Severe casualties. Therefore, it became clear that demand forecasting for the pharmaceutical supply chain was necessary [1]. The pharmaceutical market is a crucial sector of the national economy that requires particular focus due to its essential role in ensuring timely access to healthcare. Currently, there is a wide range of pharmaceutical products available in the market. These products can be categorized into durable goods, such as sanitation, hygiene, and medical devices, as well as short-term use items like medicines, medicine plant materials, and medical cosmetics [2]. The management faced significant challenges during the pandemic as a result of the substantial fluctuations and rapid increase in demand for pharmaceutical items.

The demand forecasting can actually be modelled as a time series given by:

$$Demand = f(time, assocauted\ attributes) \quad (1)$$

Here,
f denotes a function of.

The dependence of pharmaceutical demand over time makes it somewhat predictable under similar other conditions of global influencing variables. However, even the slightest of changes can derail the prediction completely.

II. THE ANFIS MODEL FOR DEMAND FORECASTING

The ANFIS can be thought of as a combination of neural networks and fuzzy logic. In this mechanism, the neural network module decides the membership functions of the fuzzy module. The ANFIS structure is depicted in figure 8.

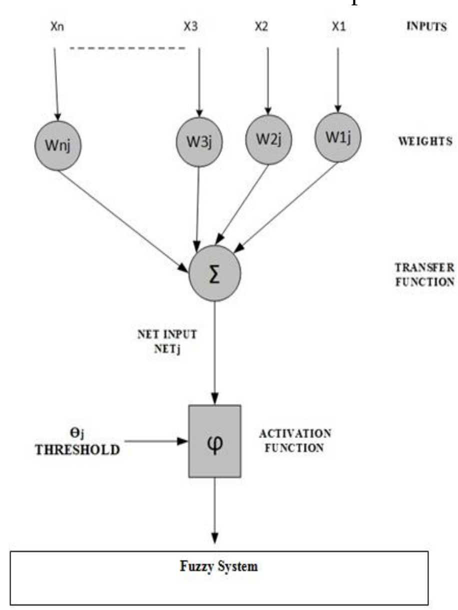

Fig.1 Block Diagram of Neuro-Fuzzy Expert Systems

III. DATA CLEANING

One of the most complex tasks related to demand forecasting is the analysis of extremely random and volatile data. Thus the proposed approach employs data cleaning techniques such as the wavelet transform.

The mathematical formulation for the wavelet transform is given by the scaling and shifting approach of the wavelet function [7].

The scaling, shifting dependence can be defined as:

$$W\varphi(Sc,Sh) = ₩[x,t] \quad (1)$$

Here,
x is the space variable
t is the time variable
₩ is the transform
sc is the scaling factor
sh is the shifting factor

The wavelet transform is an effective tool for removal of local disturbances. Pharmaceutical demands show extremely random behavior and local disturbances. Hence conventional Fourier methods do not render good results for highly fluctuating data sets. The major advantage of the wavelet transform is the fact that it is capable of handling fluctuating natured data and also local disturbances. The DWT can be defined as [8]:

$$W\Phi\ (Jo, k) = \frac{1}{\sqrt{M}}\sum_n S(n).\Phi(n)_{jo'k} \quad (2)$$

IV. PROPOSED APPRAOCH

The proposed approach employs the data claeaning followed by the back propagation based training rule for neural network weight updates.

$$w_{k+1} = w_k - (J_k J_k^T + \mu I)^{-1}(J_k^T e_k) \quad (3)$$

Here,
w_{k+1} is weight of next iteration,
w_k is weight of present iteration
J_k is the Jacobian Matrix
J_k^T is Transpose of Jacobian Matrix
e_k is error of Present Iteration
μ is step size
I is an identity matrix.

The next step is the design of a fuzy system whose membership functions are to be updated using the neural networks output [9]. Some fundamentals of the membership function for the fuzzy model are given below:

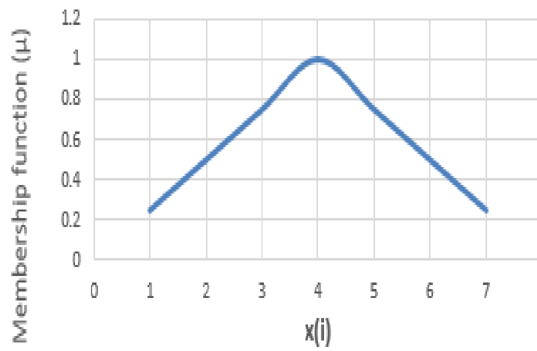

Fig.2Illustration of a Fuzzy Set

The membership functions for the fuzzy set varies in magnitude based on two major factors:

1) Input variables
2) Type of membership function.

The most commonly used membership function type is the triangular membership function given by:

$$\mu_{traingle} = max\left(min\left(\frac{x-a}{b-a},\frac{c-x}{c-b}\right),0\right) \quad (4)$$

Here,
$\mu_{traingle}$denotes the trangular membership depicted in figure 10.

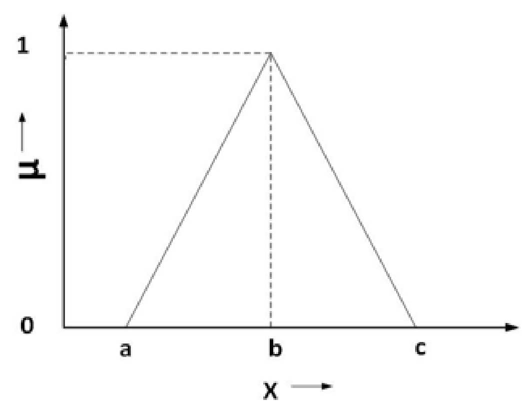

Fig.3The Triangular Membership Function

Finally, the prediction is done based on the output of the ANFIS and the perfrmance indices computed are [10]:

Mean Square Error:

It is mathematically defined as:

$$mse = \frac{1}{n}\sum_{I=1}^{N}(X - X')^2 \qquad (5)$$

Here,
X is the predicted value and
X' is the actual value and
n is the number of samples.

Mean Absolute Percentage Error (MAPE)

It is mathematically defined as:

$$MAPE = \frac{100}{M}\sum_{t=1}^{N}\frac{E-E_t|}{E_t} \qquad (6)$$

Here,
E_t and $E_t^{\sim}$ stand for the predicted and actual values respectively.

Iterations:

The iterations denote the number of cycles of training needed to reach convergence.

V. EXPERIMENTAL RESULTS

The experimental results obtained in the study are presented in this section. The system has been designed on Matlab. The data set used is extracted from Kaggle [1]. The parameters used are:

1) Date
2) Month
3) Generic Name
4) Brand Name
5) Medical Use
6) Shipped to Country
7) Sold in
8) Delivery Plant
9) External Agent Assigned/Not-Assigned
10) Price
11) Revenue
12) Commission
13) Demand/Sales

The data set parameters are depicted in figure 11.

Disease Medical Use	Company code	ship to country	Sold-to party Country Full Name	Delivery Plant	External Agent	Sales quantity	Price TC /Kg	Revenue	External commissions	Months
Psychosis; depression	5704	Mexico	Mexico	8370	lot assigne	450	$ 204.0	$ 91,800.0	$ -	Nov
Pain	5704	Thailand	Thailand	8370	lot assigne	374	$ 472.0	$1,76,528.0	$ -	Jun
Pain	5704	Vietnam	Japan	8370	Assigned	138	$ 472.0	$ 65,136.0	$ 4,186.0	Dec
Pain	5704	Australia	Australia	8370	lot assigne	227	$ 472.0	$1,07,144.0	$ -	May
Pain	5704	Singapore	Singapore	8370	lot assigne	394	$ 472.0	$1,85,968.0	$ -	Jul
Pain	5704	Singapore	Singapore	8370	lot assigne	261	$ 472.0	$1,23,192.0	$ -	Feb
Pain	5704	Thailand	Thailand	8370	Assigned	129	$ 472.0	$ 60,888.0	$ 817.0	Apr
Pain	5704	Thailand	Thailand	8370	Assigned	310	$ 472.0	$1,46,320.0	$ 5,063.3	Mar
Pain	5704	Thailand	Thailand	8370	Assigned	111	$ 472.0	$ 52,392.0	$ 1,184.0	Feb
Pain	5704	Egypt	Egypt	8370	lot assigne	109	$ 472.0	$ 51,448.0	$ -	Apr
Neuropathic pain	5887	India	India	8095	lot assigne	46	$ 500.0	$ 23,000.0	$ -	Nov
Neuropathic pain	5887	India	India	8095	lot assigne	376	$ 500.0	$1,88,000.0	$ -	Sep
Neuropathic pain	5887	India	India	8095	lot assigne	135	$ 500.0	$ 67,500.0	$ -	Jul
Neuropathic pain	5887	India	India	8095	lot assigne	379	$ 500.0	$1,89,500.0	$ -	Jul
Neuropathic pain	5887	India	India	8095	lot assigne	104	$ 500.0	$ 52,000.0	$ -	Oct
Neuropathic pain	5887	India	India	8095	Assigned	468	$ 500.0	$2,34,000.0	$ 10,296.0	Feb
Neuropathic pain	5887	Thailand	Thailand	8095	lot assigne	365	$ 500.0	$1,82,500.0	$ -	May
Neuropathic pain	5887	Thailand	Thailand	8095	lot assigne	119	$ 500.0	$ 59,500.0	$ -	Jun
Neuropathic pain	5887	Thailand	Thailand	8095	lot assigne	127	$ 500.0	$ 63,500.0	$ -	May
Neuropathic pain	5887	India	India	8095	lot assigne	254	$ 500.0	$1,27,000.0	$ -	Jul
Neuropathic pain	5887	India	India	8095	lot assigne	171	$ 500.0	$ 85,500.0	$ -	Dec
Neuropathic pain	5887	outh Afric	outh Afric	8095	Assigned	250	$ 500.0	$1,25,000.0	$ 7,833.3	Feb
Neuropathic pain	5887	India	India	8095	lot assigne	240	$ 500.0	$1,20,000.0	$ -	Jul

Fig.4 Used Data Set Parameters

The next step becomes importing the data to the MATLAB workspace so that the training and target data can be split. The split ratio used in this work has bene chosen as 70:30 as a standard thumb rule.

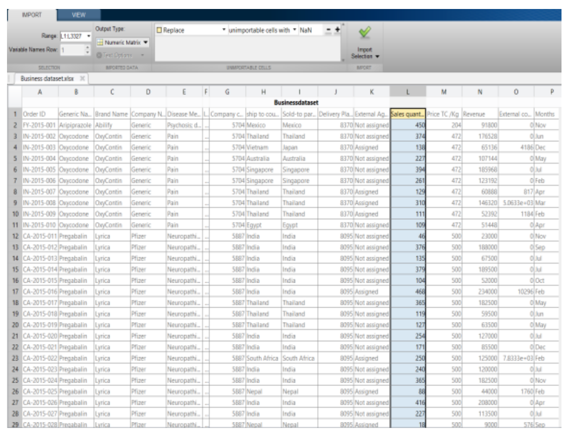

Fig.5 Data Imported to Workspace

Thecontinuous wavelt 1-D using the symlet has been used.

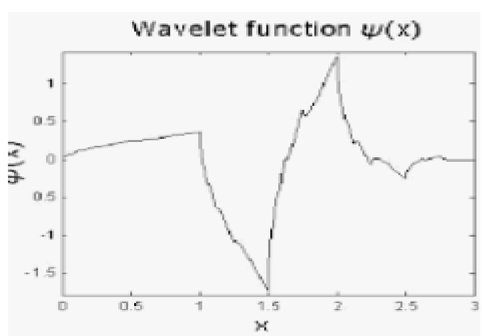

Fig.6 Symlet Wavelet Function

The decomposition has been shown in figure 13.

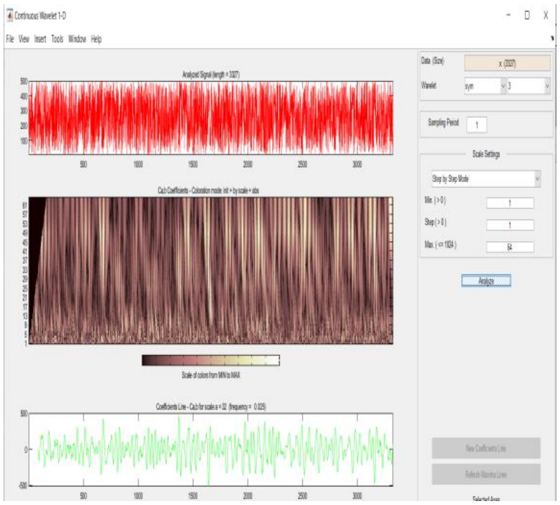

Fig.7 Symlet Decomposition of Data

The decomposition cleans the data which is then applied to the ANFIS.

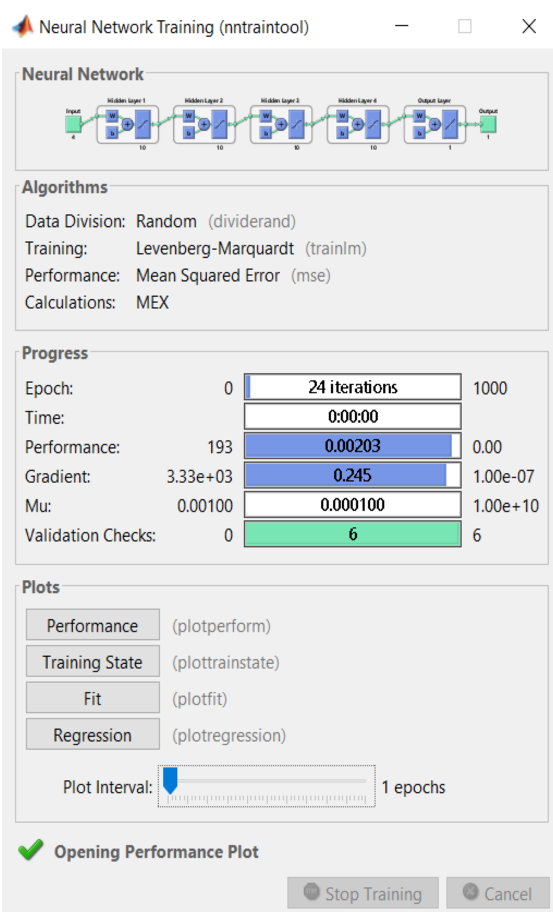

Fig.8 Designed Neural Network

The properties of the neural network have been shown in figure 14

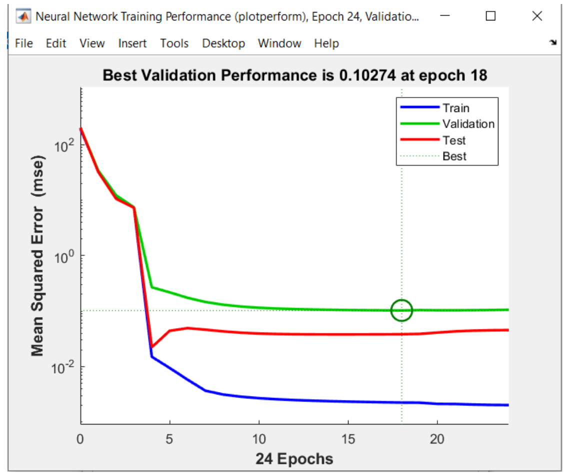

Fig.9 Iterations for convergence of Neural Network

The training epochs to convergence is depicted in figure 15.

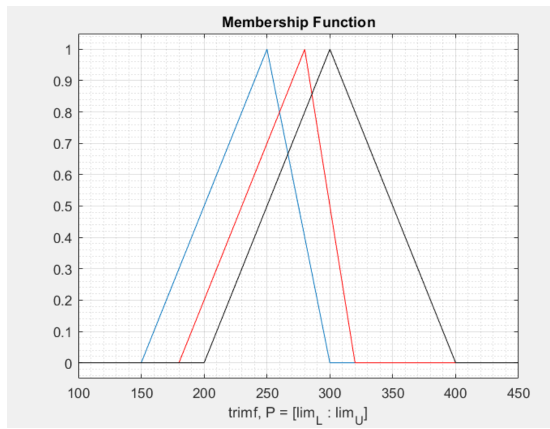

Fig.10Membership Functions of Fuzzy System

The membership functions for the Fuzzy System are depicted in figure 16. A three tier membership is used which are:

1) Low
2) Moderate
3) 3 High

The range is chosen based on the variation in the parameter values of the demand.

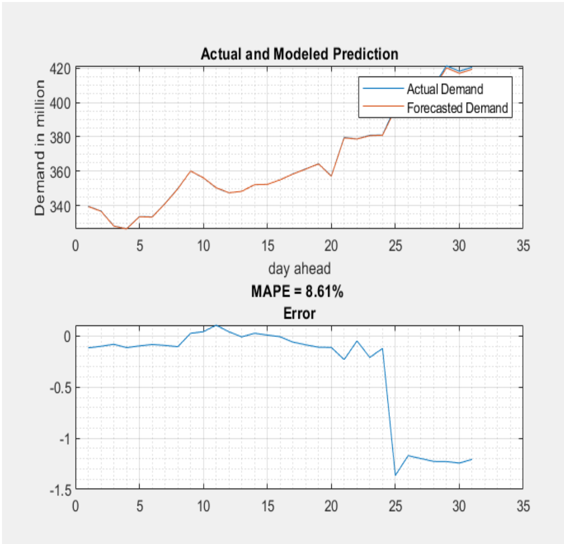

Fig.11 Modelled and Actual Prediction: MAPE Value

The MAPE obtained in the proposed work is 8.61%. Thus the accuracy can be computed as:

$$Accuracy = 100 - MAPE\,\%$$

The accuracy is thus 91.39%

Summary of Results

A summary of results of the proposed system based on the values obtained is tabulated in table 1.

Table 1. Parameter Values

S.No.	Parameter	Value
1.	Dataset	Kaggle
2.	Splitting Ratio	70:30
3.	Pre-Processing	DWT
4.	DWT Family	Symlet
5.	ANFIS Hidden Layers	4
6.	Membership Function	Triangular
7.	Levels	Low, Moderate, High
8.	Iterations	24
9.	MAPE (Proposed)	8.61%
10.	MAPE (Previous)	14%
11.	Accuracy (Previous)	86%
12.	Accuracy (Proposed)	91.39%

VI. CONCLUSION

The suggested study introduces an ANFIS-based method for predicting the demand of pharmacological data. The forecasting of pharmaceutical products is achieved through the utilization of a hybrid approach known as the DWT-ANFIS, which combines the wavelet transform and adaptive neuro fuzzy inference system. The Discrete Wavelet Transform (DWT) has been employed as a tool for data cleansing and optimization, while the Adaptive Neuro-Fuzzy Inference System (ANFIS) has been utilized for forecasting purposes. The assessment of the suggested work has been conducted using the mean absolute percentage error, regression, and iterations of the system. The suggested approach achieves a Mean Absolute Percentage Error (MAPE) of 8.61%, which is significantly lower than the 14% MAPE achieved by the earlier study. The required number of training iterations is 24. Therefore, the suggested system represents an enhancement compared to the current work in terms of the precision of predicting.

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