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Application of Portfolio Model viewed as Adaptive Neuro Fuzzy Inference System (ANFIS)

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Abstract: Now a days handling a Bank Portfolio is a open challenge in the market due to uncertain factors and risks. Asset Liability Management (ALM) which deals with adjustment of investments with respective policies and their interest rate along with market risk based on that probably bank has to manage their liabilities. In various public sector and private sector banks, they have to invest money under any portfolio to obtain maximum return on investment with less time period by looking into hazardous factors. We have already viewed Application of Portfolio in terms of Neural Network and Fuzzy Logic [1][2]. This paper have given mathematical formulation of the Portfolio problem based on case 1..n. We have analyzed input factors and its corresponding linear and non-linear membership functions and created fuzzy rule base. Here, we have used the power of Back propagation Neural Network in order to handle uncertainty of parameters which helps for decision making. First layer deals with inputs of the system and signals propagate through the middle (hidden) layer(s) to the output layer. Each link between neurons has a unique weighting value and it uses sigmoid function. This model has been constructed through Adaptive Neuro Fuzzy Inference System (ANFIS) of type 'Sugeno' in the Matlab 7.5 and finally results have been incorporated and discussed

Keywords: ALM, ANFIS, Back propagation, Fuzzy Rule base.

I. Introduction

The traditional approach and methodology can no longer cope effectively with the complexities and problems associated with large scale portfolio's. Today there is a need to attempt such complex problem with the help of soft computing techniques that could facilitate the management for solving the problem and helpful for decision making. The principal aim of this paper is to identify and rationalise the portfolio problem in terms of Neuro – Fuzzy techniques to handle uncertainty. The portfolio problem is defined as a complex decision making problem requiring effective decision making in three stages: investment policy, selection and portfolio assembly, and finally management and portfolio rationalisation. [1] In this paper mathematical formulation of the Investment problem in terms of stochastic problem (S. P.) is given and also by providing fuzzy rule base it can be represented in terms of Fuzzy Inference Engine. This problem has been attempted and viewed as an Artificial Neural Network (ANN) [2]. ANN model, used to deal with uncertainty affecting both assets (in either the portfolio or the market) and liabilities (in the form of scenario dependent payments). Uncertainties were handled by increment or decrement in market factor value, policy rate, risk level of policy and rate of interest. Based on ANN, the system is designed and trained to get high ROI with minimum risk. [3] This paper proposes a forecasting model for river breakup water levels. This paper evaluates the application of soft computing through fuzzy logic and ANN for modeling the maximum water level during river ice breakup for both flood and non-flood event years. Based on four input variable, a sample fuzzy logic model is presented. The performance of the model was evaluated for several designs including a neuro-fuzzy model created to reduce the subjectivity of expert knowledge for rule base definition. A neuro-fuzzy model able to produce qualitative models for predicting the severity of water levels associated with the spring breakup. This model equally compares with the results from multiple linear regression models.

This paper [4] uses ANFIS for predicting surface roughness in turning operation with given parameter. In order to compare the prediction accuracy of surface roughness triangular and bell shaped membership functions were used. It uses hybrid learning algorithm. ANFIS evaluates the error rate with respect to both membership functions. Result gives good accuracy by using both membership functions checked against experimental data. **Bell shaped gives more accuracy than triangular.** This paper [5] predict about the daily level of Klang Gate dam using adaptive neuro fuzzy interface system (ANFIS). The distance of gauges of stations are unknown, using various models in different time delays of inputs could demonstrate the distance between gauges and gives accurate prediction. [6] have developed new neuro-fuzzy structures called flexible neuro-fuzzy inference systems or FLEXNFIS. This approach brings more flexibility to the structure and design of neuro-fuzzy systems. After simulations, it shows that Mamdani-type systems are more suitable to approximation problems and logical-type systems may be preferred for classification problems. One research paper presents a diagnosis

system [7], specifically with skin cancer diagnosis based on an adaptive neuro-fuzzy inference system (ANFIS) algorithm. The ANFIS algorithm could be trained with the back propagation gradient descent method in permutation with the least squares method. The result of classification method showed that by using ANFIS, produces better result than with K- nearest neighbor with genetic algorithms which uses same data but gives lower accuracy results. [8] Illustrates a portfolio optimization system by using Neuro-Fuzzy framework in order to manage stock portfolio. It gives maximize return and minimize risk of a stock portfolio through diversification and right investment allocation to the particular stock under uncertainty. After evaluating the performance, the proposed Neuro Fuzzy system produces much higher accuracy when compared to other portfolio models validated by BSE Sensex stock index.

A hybrid system [9] which integrates compensatory fuzzy logic and neural networks, a new adaptive fuzzy reasoning method is proposed to make a fuzzy logic system more adaptive and more effective. This method not only adjusts the membership functions but also optimize it using compensatory learning algorithm. The convergence speed of the compensatory learning algorithm is faster than that of the conventional back propagation algorithm. Using adaptive neuro-fuzzy inference system (ANFIS) [10], develop an efficient model for prediction of cutting forces during copy milling. A linguistic model provided by ANFIS system uses knowledge embedded in the trained neural network and gives estimation of cutting forces. The ANFIS system is trained to an accuracy of 2% error for all three components, by using a back propagation training method. The error of the force values predicted by ANFIS predicts the error of the force values with the sigmoidal and gaussian membership function is only 3%, reaching an accuracy as high as 98% and with triangular membership function the average error is around 12%, with an accuracy of 92%.

II. Portfolio Problem Formulation And Its Mathematical Model

Fund organization may invest money in the following policies i.e., say $p_1, p_2 \dots p_n$. Let X_i be the amount invested in policies p_i with respect to given currency unit. N denotes year and I denotes interest rate.

Stage 1:

$N = 1$ = first year, Here, total investment at the beginning of the N^{th} year = U_N

Table 1: Portfolio based parameters

Policies	P_1	P_2	...	P_n
Investment	X_1	X_2	...	X_n
Interest Rate	$I_1 \%$	$I_2 \%$	...	$I_n \%$

Case 1: I_1 for given X_j is fixed.

Case 2: The interest rate on a given policy may depend on the number of units or investment amount i.e., interest rate may be different for different brackets of investments in particular policy.

Input $U_N, I_1, I_2 \dots I_n$ and n

R_N = Return on investment at the end of year N for the investment U_N made at the beginning of N^{th} year.

$$\text{Maximize } R_N = \sum_{i=1}^n X_i * (I_i / 100)$$

Subject to

$$\sum_{i=1}^n X_i = U_N \quad (X_i \geq 0 \text{ for } i=1 \text{ to } n)$$

is the total amount available for investment in all the policies at the beginning of year N .

Then finally, we have,

$$U_N' = (U_N + R_N) - d_N, \quad d_N \geq 0$$

Where d_N is the depositors amount with interest subtracted U_N' is the total return at the end of year N including the accrued interest.

Stage 2:

Where $N = 2$

$N \geq 2$ and $N \leq N$

Input $U_N, I_1, I_2, \dots, I_n$ and n

$$\text{Maximize } R_N = \sum_{i=1}^n X_i * (I_i / 100)$$

Subject to

$$\sum_{i=1}^n X_i = U_{N-1}' + U_N \quad (X_i \geq 0 \text{ for } i = 1(1)n)$$

Finally, we have,

$$U_N' = (U_{N-1}' + U_N) + R_N - d_N, \quad d_N \geq 0$$

Stage 3:

Where $N = N$

Input $U_N, I_1, I_2, \dots, I_n$ and n

$$\text{Maximize } R_N = \sum_{i=1}^n X_i * (I_i / 100)$$

Subject to

$$\sum_{i=1}^n X_i = U_{N-1}' + U_N \quad (X_i \geq 0 \text{ for } i = 1(1)n)$$

if $N=N$ then $d_N = 0$

Finally, we have,

$$U_N' = (U_{N-1}' + U_N) + R_N - d_N, \quad d_N \geq 0$$

When the random event occurs, then one needs to take decision, as to how much to invest, for what time period and with what percentage rate in order to obtain maximum returns. At that time, one of the scenarios comes in picture; market scenario may be Normal, Bad, Good or Very Good.

We have for the expected value of the M equally likely returns for asset I when random event occurs.

$$\hat{R}_i = \sum_{j=1}^M R_{ij} / M$$

if the outcomes are not equally likely and if P_{ij} is the probability of the j^{th} return on the i^{th} asset, then expected return is:

$$\hat{R}_i = \sum_{j=1}^M P_{ij} * R_{ij}$$

III. Proposed Architecture

This architecture consists of five layers based on ANFIS model includes fuzzy layer, product layer, normalized layer, de-fuzzy layer and summation layer.

Layer 1:

Each node ' i ' in this layer generates a membership grades. It is a fuzzy layer in which X, Y, Z are input nodes. $A_1, A_2, A_3, B_1, B_2, B_3, C_1, C_2, C_3$ are linguistic labels used for dividing the membership function. The node function described as:

$$\begin{aligned} O^1_i &= \mu_{A_i}(x) & i=1,2,3 \\ O^1_j &= \mu_{B_j}(y) & j=1,2,3 \\ O^1_k &= \mu_{C_k}(z) & k=1,2,3 \end{aligned}$$

where x, y, z are input nodes and O^1_i, O^1_j and O^1_k are output functions of layer 1, $\mu_{A_i}(x), \mu_{B_j}(y)$ and $\mu_{C_k}(z)$ are membership functions.

Layer2:

Each node in this product layer applies a scaling factor to incoming signals and sends the product out represented by circle, calculates 'firing strength' of each rule via multiplication.

$$O^2_i = W_i = \mu_{Ai}(x) * \mu_{Bi}(x) * \mu_{Ci}(x) \quad i = 1, 2, 3$$

Where O^2_i is the output function of layer 2

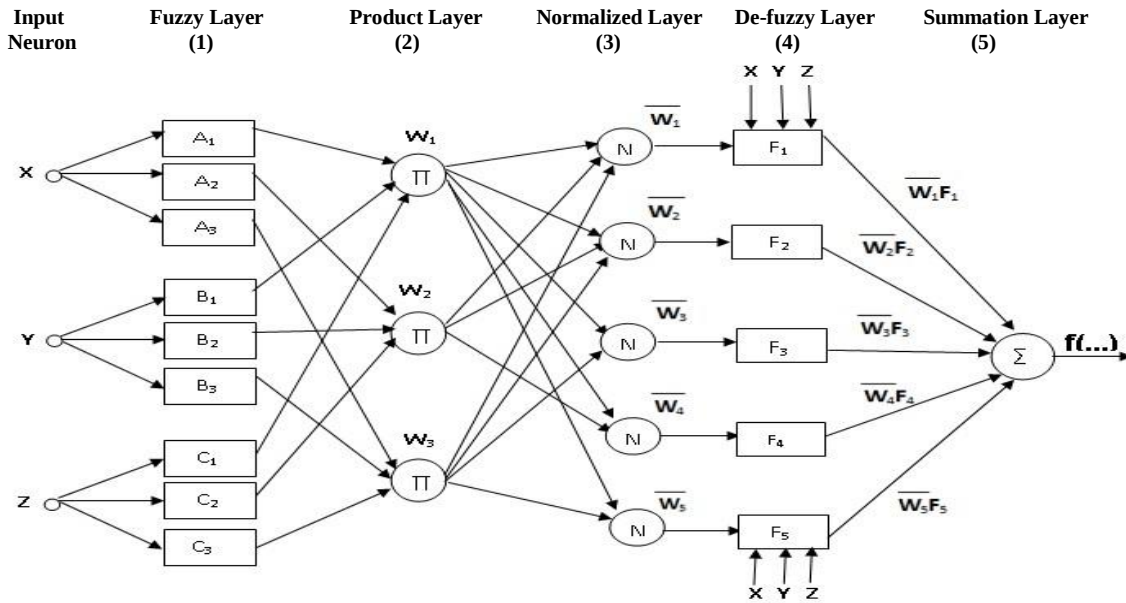


Fig 1: Proposed Portfolio Model Architecture

Layer 3:

Every node on this normalized layer calculates the weights according to ratio of the i^{th} Fuzzy rule firing strength to combine all fuzzy rules firing strengths. The i^{th} node calculate ratio of i^{th} rule's strength to the sum of all rules firing strength.

$$O^3_i = \bar{W}_i = \frac{W_i}{W_1 + W_2 + W_3} \quad i = 1, 2, 3, 4, 5$$

Where O^3_i is the output function of layer 3.

Layer 4:

Each node in this de-fuzzy layer is an adaptive node, noticed by square which execute the linear aggrement of system input signals X, Y, Z by implies of consequent parameters. Every node ' i ' in this layer is a square node with node function.

$$O^4_i = \bar{W}_i F_i = \bar{W}_i (a_i x + b_i y + c_i z + r_i) \quad i = 1, 2, 3, 4, 5$$

Where O^4_i is the output function of layer 4.

Layer 5:

In this summation layer, only one fixed node is marked by square which calculates output signal as summing up all signals that is overall output.

$$O^5_i = \sum_i \bar{W}_i F_i = \frac{\sum_i \bar{W}_i F_i}{\sum_i \bar{W}_i} \quad i = 1, 2, 3, 4, 5$$

Where O^5_i is the output function of layer 5.

IV. Anfis model structure

According to the Fig 1, experiment has been setup through ANFIS and following architecture has been generated through ANFIS model shown in Fig 2.

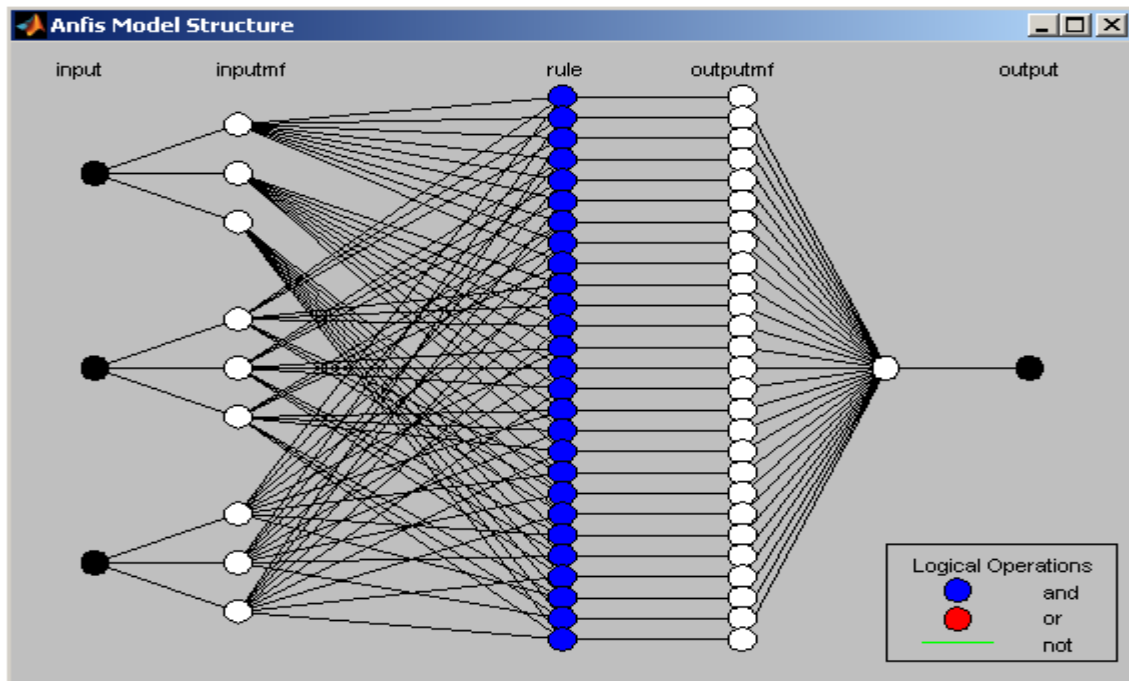


Fig 2: Portfolio Model Architecture generated through ANFIS

V. Usage Of BackPropagation (BP) Algorithm

BP algorithm usage is derived in two phases:

Phase 1: Propagation

Each propagation involves the following steps:

- [1] Forward propagation of a training pattern's input through the neural network in order to generate the propagation's output activations.
- [2] Backward propagation of the propagation's output activations through the neural network using the training pattern target in order to generate the deltas of all output and hidden neurons.

Phase 2: Weight update

For each weight-synapse follow the following steps:

- Multiply its output delta and input activation to get the gradient of the weight.
- Bring the weight in the opposite direction of the gradient by subtracting a ratio of it from the weight.

This ratio influences the speed and quality of learning; it is called the *learning rate*. The sign of the gradient of a weight indicates where the error is increasing, this is why the weight must be updated in the opposite direction. Repeat phase 1 and 2 until the performance of the network is satisfactory. As the algorithm's name implies, the errors propagate backwards from the output nodes to the input nodes. Technically speaking, back propagation calculates the gradient of the error of the network regarding the network's modifiable weights. This gradient is almost always used to find weights that minimize the error.

VI. Fuzzy Rule Base

A set of fuzzy rules for the invested units

- Rule 1: If units (no. of units=min) and int_rate (interest rate=high) and risk (risk =low) then **Investment is High.**
- Rule 2: If units (no. of units=moderate) and int_rate (interest rate=moderate) and risk (risk =low) then **Investment is Moderate.**
- Rule 3: If units (no. of units=moderate) and int_rate (interest rate=high) and risk (risk =low) then **Investment is High.**
- Rule 4: If units (no. of units=high) and int_rate (interest rate=moderate) and risk (risk =low) then **Investment is Moderate.**

- Rule 5: If units (no. of units=high) and int_rate (interest rate=high) and risk (risk =low) then **Investment is High.**

VII. ANFIS Experiment Setup

Experiment setup details for triangular, trapezoidal and a gbell membership function (mf) varies in terms of parameters and data ranges. Typical setup details of trapezoidal mf have been given in Table 2.

Table 2: Setup details w. r. t. Triangular membership function

Name= 'NeuroFuzzy2' Type='sugeno' Version= 2				
NumInputs=3	NumOutputs=1	NumRules=5	AndMethod='prod' OrMethod='prod' ImpMethod='prod'	AggMethod='sum' DefuzzMethod='wt aver'
[Input1]	[Input2]	[Input3]	[Output1]	[Rules]
Name='Units' Range=[100 1000] NumMFs=3 MF1='High':trimf,[576 784.52 996] MF2='Min':trimf,[101.1 9 290 440] MF3='Moderate':trimf,[3 47 508.3 666]	Name='int_rate' Range=[3 10] NumMFs=3 MF1='Low':trimf,[3 4.5 6] MF2='Marginal':trimf,[5.2 6.60 7.71] MF3='High':trimf,[7 8.5 10]	Name='m_risk' Range=[0 3] NumMFs=3 MF1='Low':trimf,[0 0.5 1] MF2='Marginal':trimf,[0.77 4 1.5 2.14] MF3='High':trimf,[1.8 2.5 3]	Name='output1' Range=[0 1] NumMFs=3 MF1='Low':linear,[100 150 200 275 350] MF2='Moderate':linear,[300 360 445 550 650] MF3='High':linear,[600 725 800 925 1000]	2 3 1, 3 (1) : 1 3 2 1, 2 (1) : 1 3 3 1, 3 (1) : 1 1 2 1, 2 (1) : 1 1 3 1, 3 (1) : 1

VIII. ANFIS Results

Following results have been generated through ANFIS Editor and given in Table 3.

Table 3: Inputs and outputs based on different membership functions

Inputs			Outputs (Units to be invested)		
Units	Interest rate	Risk	Triangular	Gbell	Trapezoidal
500	9.07	1.06	0.0539	0.393	0.0984
690	5.31	1.04	0.0336	0.537	0.359
695	9.26	1.11	0.00998	0.438	0.0976
817	5.42	1.05	0.3	0.794	0.908
500	3.23	2.04	0.019	1.04	0.979
690	5.31	2.33	0.013	1.08	1.2
695	9.26	2.42	0.054	1.17	1.07
817	5.42	2.72	0.146	0.649	0.412
888	9.36	2.97	0.000127	0.499	0.04

In Fig. 3, output part that is units to be invested have been analysed with the help of triangular, trapezoidal and

gbell membership functions. Triangular member function and Trapezoidal membership function are of type linear and Gbell membership function is of type non-linear.

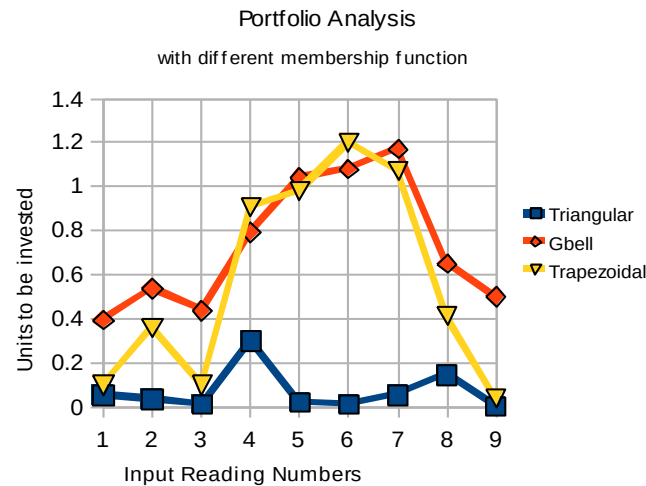


Figure 3: Result Analysis

ANFIS information have been generated through ANFIS editor itself and that is shown in table 4.

Table 4: ANFIS information

ANFIS information Details
Number of nodes: 78
Number of linear parameters: 108
Number of nonlinear parameters: 27
Total number of parameters: 135
Number of training data pairs: 4
Number of checking data pairs: 0
Number of fuzzy rules: 27

IX. Conclusion

Portfolio analysis has been carried out in figure 3, output part that is units to be invested have been analyzed with the help of triangular, trapezoidal and gbell membership functions. On the basis of analysis so far we may conclude that non-linear membership function i.e., gbell works more prominently than linear functions because the nature of input data is non-linear and input is also depends upon three different sub-categories.

Relationships in the data modeled by "if-then" rules which are easy to understand, verify, and extend. Fuzzy rules are extracted and Back propagation algorithm was applied by using ANFIS model. ANFIS loaded the given data, generate Fuzzy Inference system (FIS) and train the network which helps to obtain maximum Return on Investment. Finally system helps in deciding in which policy to invest the money by considering all the related factors like units, interest rate and market risk of the policy.

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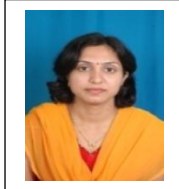
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