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Estimation and Approximation Using Neuro-Fuzzy Systems

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Abstract—Estimation and Approximation plays an important role in planning for future. People especially the business leaders, who understand the significance of estimation, practice it very often. The act of estimation or approximation involves analyzing historical data pertaining to domain, current trends and expectations of people connected to it. Exercising estimation is not only complicated due to technological change in the world around, but also due to complexity of the problems. Traditional numerical based techniques for solution of ill-defined non-linear real world problems are not sufficient. Hence, there is a need of some robust methodologies which can deal with dynamic environment, imprecise facts and uncertainty in the available data to achieve practical applicability at low cost. Soft computing seeks to solve class of problems not suited for traditional algorithmic approaches.

To address the common problems in business of inexactness, some models are put forward for servicing, support and monitoring by approximating and estimating important outcomes. This work illustrates some very general yet widespread problems which are of interest to common people. The suggested approaches can overcome the fuzziness in traditional methods by predicting some future events and getting better control on business. This includes study of various neuro-fuzzy architectures and their possible applications in various areas, where decision-making using classical methods fail.

Index Terms—Soft Computing, Neuro-Fuzzy System, Estimation and Approximation, Decision-making, Uncertainty, Non-linearity.

I. Introduction

The businesses in today's era are becoming increasingly complex and they are continually challenged with dynamism of environment. Lot of organizations are experiencing problems in taking unstructured decisions and handling unseen events occurring every day, leading to business failures. These unseen events are not only dynamic in nature, but also bring along ambiguity and uncertainty with them. All the real-world problems may not be represented properly using traditional approaches due to the lack of precise knowledge, their non-linear behavior or their high degree of uncertainty. In an attempt to simplify the complications of the real-world, these models tend to overlook the actual behavior of business, which make them inefficient to use and sometimes does not give the desired results. Many techniques ranging from regression analysis to time series are available and being regularly used by organizations to generate forecasts, but the methods currently in use somewhere are incapable of prediction of future events. A systematic consideration of fuzzy data in managing complex issues of today and predicting the uncertain issues of tomorrow can only help them succeed.

The aim of this work is to propose solutions to some real-world problems which suffer from uncertainty and vagueness with the intention to study the methods currently in practice. Through proper study and observation, the identification of uncertain attributes and the fuzziness involved in each problem is done and subsequently handled with application of Neuro-fuzzy methodologies, where huge data can be handled by trainability and adaptation of neural network and fuzzy logic is the way out to vagueness. An attempt is made to find out how the hybrid soft computing approaches, particularly combination of different types of neural network with fuzzy logic, can be applied for the purpose of estimation and approximation in real-world problems.

Accuracy has become dreamboat for researchers, but in the hunt for accuracy they sometimes ignore important things. According to Fortuna [Fortuna, 2001][1] the basic principle of soft computing is its combined use of new computation techniques that allow it to achieve a higher tolerance level towards imprecision and approximation. As opposed to conventional methods, soft computing methodologies mimic consciousness and cognition in several ways like learning from experience, performing input-output mapping etc. by simulating biological process through parallelization. Estimation or more specifically, prediction is an art where business leaders try to minimize uncertainty by identifying and evaluating the associated risk. The terms prediction and forecasting are used in business exchangeably and so is here.

A business which can adjust itself with the changing needs of market and its customers can have a bright

future and can go long. Statistical techniques are mostly used by business people for calculating a trend or for having an insight in future. Accurate predictions allow business leaders to be ready for future ups and downs by foretelling the future with precision. To survive in the competitive market and to be able to fulfill expectations have become crucial for the business people. Apparently, this cannot be achieved without effectively foreseeing some important future events. This in turn gives them chance to attract new customers, retain existing customers, understand present scenario and possibly solve problems which may occur in future. Now-a-days soft computing methodologies are deployed as an alternative to handle all problems discussed above. Soft computing seeks to solve the class of computationally hard problems which are not suited for traditional algorithmic approaches.

In view of above discussion, an effort is made to propose hybrid soft computing solutions to some problems from real-world. The simulation environment is based on MATLAB software package, which is used as the tool for modeling, development and testing of proposed techniques for estimation and approximation. The paper is organized as follows: Section II discussed related work using soft computing techniques focusing particularly on Artificial Neural Networks (ANNS) and Fuzzy Logic in the area of estimation. Section III proposes various methodologies for estimation and approximation considering problems faced in real time due to inherent uncertainty in them. Based on the proposed solutions, section IV throws light on the observations and results obtained thereof. Section V concludes by giving direction to possible future work.

II. Related Work

Typical real-world situations are full of uncertainty and vagueness and this uncertainty may occur due to many reasons; it may be caused by vagueness in the language or by imprecision in measurement of related factors. In such situations, linguistic variables are used to describe situations, or sometimes to quantify physical objects. It was Lotfi Zadeh [24], who realized that crisp set theory is incapable of representing these situations and objects and do not provide adequate representation for most cases. He argued that humans do not reason precise numerical values, instead using categories which are not based on numerical values. Artificial Neural Networks introduced by McCulloch and Pitt [18], in 1940s based on the observation that human brain consist of numerous interconnected neurons encapsulates the most rare thing in this world - human intelligence. The advantage of ANNs over conventional computers lies is in its high parallelism. It is becoming widely accepted that the advent of ANN will open new understanding into how to simplify programming and algorithm design for a given end and for a wide range of ends [11]. Although there are some limitations of ANN too, like designing neural networks, long training periods, and possibility of over-fitting, but taking a little care, performing these tasks patiently and in right manner may generate fantastic results.

ANNs have been used as computational tools for data quality identification because of the belief that they have greater predictive power than signal analysis techniques [12]. However, fuzzy set theory plays an important role in dealing with uncertainty when making decisions in data fusion [4]. An in-depth study focusing on the study pertaining to the behavior and applications of fuzzy logic, neural networks and their combination systems can be found in Arora & Saini [2]. The summary of some of the existing work on the topics of interest of this work viz. bankruptcy prediction of firms, bankruptcy prediction of financially distressed firms, student academic performance prediction, forecasting daily demand of cash at ATM based particularly on soft computing techniques can be seen in Table I below.

Hence, the conclusions drawn from literature review suggest that neural networks approach outperforms conventional approaches due to their capabilities of high parallelism and robustness and fuzzy logic can successfully deal with inherent uncertainty. But at the same time it is felt that there are many domains important from business viewpoint which are yet to be touched and tested for possible applications of selective neural networks and fuzzy logic.

III. Proposed Methodologies for Estimation and Approximation

Estimation is one the most studied functionality of ANN where they are found to be capable of giving satisfactory outcome. A lot of research has been carried out to study the strengths of neuro-fuzzy networks. In two separate works Wu [23] and Ying-Ming Wang [24] verified that ANFIS model comprising the neural network's adaptive capability and the fuzzy logic's qualitative approximation outperforms artificial neural networks. Arora et al. [3] studied the risk of not taking health insurance and developed ANFIS model for determining the degree to which an insurance seeker is exposed to risk if he fails to take insurance. The scope of integration of these two techniques cannot be limited to specific type of applications or to certain domain. There are a variety of neural networks which can be possibly combined with fuzzy logic to take the advantage of the two extremes. These models may result into fruitful applications in their respective areas. The problems considered to prove the applicability of neuro-fuzzy networks in real world are: Bankruptcy prediction of companies, bankruptcy prediction of financially distressed companies, student's academic performance and ATM cash management. Fuzzy Logic Tool box of MATLAB has been used for simulations and evaluation of the model.

Table 1. Existing Work Utilizing Soft Computing Techniques

Sr.	Application	Technique	Findings
1.	Bankruptcy prediction Lensberg et al. (2006) [14]	Genetic Programming (GP)	GP is better than the traditional probit model
2.	Bankruptcy prediction Tam and Kiang [16]	Artificial Neural Network (ANN)	Multilayer Perceptron architecture more accurate than MDA, Linear Regression, k-Nearest Neighbor, and ID3 algorithm
3.	Bankruptcy prediction Jo, Han and Lee [13]	Comparison of Artificial Neural Network (ANN), Multiple Discriminant Analysis (MDA) and Case Based Reasoning (CBR)	Performance Rate 83.79% with ANN, 82.22% with MDA, and 81.52% with CBR
4.	Bankruptcy prediction Shin and Lee [19]	Genetic Algorithm (GA)	Rule extraction approach using Genetic Algorithm is promising
5.	Bankruptcy prediction Zanganeh et al. [26]	Adaptive Neuro-Fuzzy Inference System (ANFIS)	Fuzzy logic combined with time series proves to be the best method
6.	Bankruptcy prediction Atiya A. [5]	Neural Networks	Nonlinear approach like neural network superior to linear approach like statistical approach
7.	Bankruptcy prediction Shin et al., (2005) [20]	Support Vector Machines (SVM) to compare the results with Neural Networks	More accuracy and generalization of SVM compared with the NN's
8.	Bankruptcy prediction Anandarajan et al. [1]	Generic Algorithm (GA) using back propagation networks	Misclassification cost of genetic algorithm based neural network is lowest in comparison to Back-propagation neural network and multiple discriminant analysis
9.	Student learning assessment outcome Ma and Zhou [15]	Integrated fuzzy set approach	Use of Fuzzy set to determine the assessment criteria and their corresponding weights.
10.	Student academic evaluation Biswas [6]	Fuzzy set Approach	Fuzzy theory can provide a model of subjective judgments
11.	Evaluation of student answer scripts Chen and Lee [7]	Fuzzy membership function values and probability theory	Counter some drawbacks of the method proposed by Biswas
12.	Academic decision support system Deniz & Ersan [8]	Several ways to analyze student's performance data	Showed potential of academic data mining and use of academic decision-support software
13.	Forecast daily cash demand and optimal cash load for ATM Simutis et al. (2008) [18]	Artificial Neural Network (ANN) and Support Vector Regression (SVR)	Slightly better results of forecasting are achieved with flexible neural network than support vector regression
14.	Predictions of ATM cash demands Teddy and Ng [22]	Cerebellar Model Articulation Controller (CMAC) associative memory network	Proposal to implement local learning technique
15.	Daily ATM cash demand Ramirez et al. [17]	Multilayer Perceptron (MLP) and Support Vector Machine (SVM)	MLP presented the best results
16.	Minimizing daily amount of stocked money Dijonas et al. [9]	Neural Networks and multi-agent technology	Data gathering by agents and neural network for prognosis and optimization

A. Time Series Model for Bankruptcy Prediction via Adaptive Neuro-Fuzzy Inference System

Any company which is into business runs with lots of risks and uncertainties like risk of investment, expenditures and other operations besides the biggest risk is financial crisis. No company is ever protected against bankruptcy. Those who get affected by bankruptcy are the company's stakeholders; owners, employees, shareholders, top-level managers, investors, and key regulators. The best solution for all these people is to be able to predict bankruptcy status of the company. Bankruptcy is an alarming situation which can take business giants from best of their financial status to the most undesirable state of bankruptcy. There can be many reasons for a company to go bankrupt viz. poor financial planning and uncontrolled spending, unexpected disasters, over-fired operating expenses, market conditions, financing from investors and above all poor decision making.

The challenging task of predicting bankruptcy includes the analysis of financial status of the company considering its historical data, past performance of the financial ratios, measurement of company's competitive advantage etc. An important step is to study and understand the factors behind bankruptcy and predicting it timely to take preventive measures. The challenge is to propose a generalized model suitable to all types of companies irrespective of the type of industry they belong to. In this view, a model has been proposed to analyze the dependency of enterprises on their financial ratios for predicting bankruptcy using artificial neural networks combined with fuzzy logic. A time series prediction model of bankruptcy via Adaptive Neuro-Fuzzy Inference System (ANFIS) is formulated, capable of predicting the bankruptcy of a firm for any future time. The data used in this study has been extracted from the past financial records of ongoing and failed enterprises. The extracted financial ratios are preprocessed by calculating Altman's Z-score before feeding into Time series model. The Time series prediction is carried out using ANFIS to predict the bankruptcy at any given time which overcomes the limitation of Altman's basic model of bankruptcy prediction. Numerical illustration is provided to demonstrate the efficiency of proposed model.

The motivation for this work is the success of Altman's model in determining the financial status of a company. The factors of Altman are used in developing and implementing a quantitative model to predict bankruptcy of a company. Altman's z-score model also known as zeta model combined various measures of profitability or risk. The model demonstrated a company's risk of bankruptcy. Altman's model was found to be very accurate by correctly predicting bankruptcy with 94% success. The results of experiment show that the training error is higher than checking error. It is observed that prediction error decreases for first three years and then starts increasing from the 4th year onwards. For the two runs performed for 4th year, it can be concluded that for better prediction of farther years, ANFIS requires longer training with more number of training data. Table II shows the performance of prediction done by ANFIS model for next 4 years obtained using 1000 sample training data sets and 3 gbell membership functions.

Table 2. Statistics for Comparison of Prediction Model Computation

Prediction	Training Data	Training RMSE	Checking RMSE	Prediction Error
t + 1	1000	0.5994	0.0847	0.8506
t + 2	1000	0.6441	1.0451	0.6511
t + 3	1000	0.3659	0.2954	0.3872
t + 4	1000	0.4397	0.3026	0.6182
t + 4	2000	0.4725	0.3911	0.3204

The financial position of a firm and its susceptibility for bankruptcy may critically affect the health of stakeholders like shareholders, creditors, employees, and business partners. Hence, the bankruptcy projection is of great interest to researchers and has become a common research topic in multiple disciplines. A large number of standardized financial ratios are utilized for the assessment of the financial state of a company. Bankruptcy prediction may help the investors to avoid huge economic losses. Financial ratios are also used by security analysts for the purpose of comparison between the strengths and weaknesses of different firms. Combined with Altman's Z-score, ANFIS based time series prediction model is unique and novel as it is simple, reliable and the chances of mis-predictions are least. The model can be used by banks as a loan approval system. It can serve as a screening model for commercial loans for loan examination and loan review. It can also be used by the managers of the enterprises to take preventive measures to deal with financial crises. Hence, a methodology which can predict bankruptcy for a company would benefit the whole community.

B. Bankruptcy Prediction of Financially Distressed Companies using Independent Component Analysis and Fuzzy Support Vector Machines

Financial distress is hard to define precisely. Financial distress is a situation where the operating cash flows of a company are not sufficient to satisfy its present commitments and the firm is forced to take corrective action. The inability of such a company to generate enough cash flow to make the required payment, such as trade credits or interest expenses leads to financial distress. This is true partly because of the variety of events like dividend reductions, plant closings, losses, layoffs, CEO resignations etc.

One of the important reasons for financial distress of a company is inexperienced management with dumb strategy and poor control leading to fraud. Financial distress does not always lead to termination of the company. Some companies take preventive measures to fight with financial crisis to come out from the dangers of falling in bankruptcy situation. A financially distressed company can deal with this situation in variety of ways. Some of the responses to financial distress can be changes in managerial control, winding up the current company, getting a significant stake in the firm from outside investor, restructuring existing debt facilities etc. Bankruptcy is an alarming situation which demands some good prediction model that can be utilized by business leaders of such financially distressed company to foresee its future status. Hence, the reason behind choosing this topic is to study the danger of a financially distressed company to slip to bankruptcy and to warn such a company for possible bankruptcy in future so that it can take best measures to gradually escape from the danger

line and evolve.

A model has been proposed to predict the bankruptcy status of financially distressed enterprises on some of their prominent financial ratios. To develop such model, a sample of companies which are financially distressed but not yet bankrupt is considered for conducting experiments. The data extracted from financial reports of financially distressed companies for past five year forms the basis for carrying out prediction. Independent Component Analysis has been applied on the input dataset comprising of financial ratios to reduce dependency among inputs thereby choosing the most significant ratios to be considered as input to Fuzzy support vector machines (FSVM).

A data set of size 1030 consisting of five variables was used for training and of size 350 was used for testing the network's performance. In this way the model predicts the bankruptcy status of the enterprises with minimal training errors. A linguistic diagnosis of failure or financial problems of the enterprises is done using the fuzzy rule-base for support vector machines. The proposed model can be utilized by stakeholders of a financial distressed company for determining its future status. It can also be used by managers of the enterprises to take preventive measures to deal with financial crises. Table III presents demonstrates some sample data to validate that the prediction error is almost insignificant.

Table 3. Sample Data for Assessing Performance of FSVM

Expected Output	Predicted Output	Expected Output	Predicted Output	Expected Output	Predicted Output	Expected Output	Predicted Output
1	0.900003	1	1.099985	2	2.009353	2	1.899753
1	1.100012	1	1.017911	2	2.017060	2	1.899672
1	1.100236	1	1.002502	2	1.953372	2	1.900124
1	0.920219	1	1.100306	2	1.925463	2	1.899826
1	1.044410	1	0.899946	2	1.899963	2	1.899770
1	1.100165	1	1.100452	2	1.900450	2	1.931154
1	1.025397	1	0.923510	2	1.900006	2	1.899895
1	1.004706	1	0.933673	2	1.899522	2	1.899875
1	1.082617	1	1.023058	2	1.901749	2	1.942002
1	1.059447	1	0.900021	2	1.899799	2	2.100002
1	1.099832	1	0.899938	2	1.900119	2	1.901982
1	1.099966	1	1.042299	2	1.899853	2	1.916765
1	0.899755	1	1.093743	2	1.900044	2	1.900166
1	1.100094	1	1.016680	2	2.099997	2	1.909298
1	1.100258	1	1.099901	2	2.075546	2	1.900144
1	1.099918	1	0.908523	2	1.908368	2	1.902712

Simulation results show that the fuzzy support vector machine generates 342 support vectors with default cost 1 and default curvature $\left(\frac{1}{k}=\frac{1}{5}=0.2\right)$ and converges in 202 iterations in classification mode while in regression mode; FSVM generates 314 support vectors with least iterations 816 to converge using curvature value 5 but has more MSE than other curvature values. FSVM using regression model depicts that with better curvature, it can achieve better prediction accuracy. A comparative analysis of clustering power of FSVM with ANFIS shows that former has superior clustering ability.

It can be concluded that the non-linear nature of financial figures can be reasonably handled in the proposed model. FSVM shows good learning and predicting capabilities while dealing effectively with uncertainty. The model is expected to provide benefits to Bankers, lenders in lending decisions and other stakeholders in their investment decisions with a future perspective.

C. Fuzzy Probabilistic Neural Network for Student's Academic Performance Prediction

Education has become business these days. The privatization of educational institutes has caused the shift from educational institutions to a business. In general sense, the education system comprises of simple practices for conducting classes, taking examination, evaluating students and then taking corrective steps for weak students. Institutes now-a-days emphasize on improvising teaching methodologies to increase their involvement in class. This has increased the burden on the shoulders of educationalists to do analysis of students' capabilities, behavior etc. to understand difficulties of students in classroom and to improve their grasping. By doing this the potential problems faced by students can be identified for possible considerations. With the help of a good predictive model, which can predict student's performance, teachers can give directions to the student to focus more and put in required effort right from the beginning of the study term.

A Fuzzy Probabilistic Neural Network model has been proposed which enables the design of an easy-to-use, personalized student performance prediction component. The proposed model allows prediction of students' academic performance based on some of their qualitative observations. A hybridized fuzzy neural network model successfully handles reasoning with imprecise information, and enables representation of student modeling in the linguistic form - the same way the human teachers do. The model is designed, developed and tested in MATLAB which considers factors like age, gender, education, past performance, work status, study environment etc. for performance prediction of students. A fuzzy Probabilistic Neural Network (FPNN) has been designed using MATLAB and analyzed on a 760 samples of training dataset consisting of above 18 factors as inputs

to the network.

The initial data is cross-validated in the ratio 3:1 obtaining training and test dataset. Cross-validation is basically used to inspect the performance of a neural network in result prediction in terms of sampling variation. This statistical technique is avoids the chances of FPNN to overfit the data. The FPNN is then trained by the membership degree matrix 570X18 formed from 570 samples of 18 factored vectors. Once FPNN is trained, it calculates the probabilities of each training data to belong to each class as seen in Table 4 based on factors relevant to his behavioral characteristics, family history and educational interest etc. This table helps in determining the likelihood of each student to belong to every class.

Table 4. FSVM Class Probabilities of Sample Training Data

Sample#	Class1-Good	Class2-Average	Class3-Poor
1	1.0000	0.0000	0.0000
2	1.0000	0.0000	0.0000
3	0.6776	0.0136	0.3088
4	0.6482	0.0216	0.3302
5	0.5927	0.0210	0.3863
6	0.5982	0.0216	0.3803
7	0.6700	0.0202	0.3098
8	0.6181	0.0297	0.3522
9	0.6944	0.0098	0.2958
10	0.6038	0.0298	0.3664
11	0.6124	0.0294	0.3582

Sample#	Class1-Good	Class2-Average	Class3-Poor
:	:	:	:
561	0.0804	0.3916	0.5280
562	0.2816	0.1442	0.5742
563	0.4621	0.0556	0.4823
564	0.1737	0.2336	0.5927
565	0.1317	0.2922	0.5761
566	0.3157	0.1285	0.5559
567	0.0927	0.3954	0.5119
568	0.2785	0.0985	0.6230
569	0.0909	0.3585	0.5506
570	0.3806	0.1051	0.5143

The experiments conducted demonstrate that the overall prediction error is 2.6667 and the root mean square error is 0.0265. With 18 neurons in the input layer and neurons equal to the number of training exemplar patterns in the hidden layer, the network is found to achieve a near expected correct detection. The basic reason behind misclassification is observed due to the presence of noise in the test data. The cross-validation method improves the generalization capability of the network. Separate experiments were conducted with and without cross-validation method for training the FPNN.

A comparison of PNN predictions with two different data set sizes reveals some important results like: PNN is found to converge in less time in contrast to a typical back propagation network which takes hours to be trained. The test results are near to the expected values with an average prediction accuracy of 98.56%. These results of experimentation indicate that the model outperforms traditional back-propagation neural networks as well as statistical models. The model may provide dual advantage to the educational institutions; first by helping teachers to amend their teaching methodology based on the level of students thereby improving students' performances and secondly classifying the likely successful and unsuccessful students.

D. Approximating Methodology: Managing Cash in Automated Teller Machines using Fuzzy ARTMAP Network

The basic meaning of cash management is to maintain the amount of cash inflow and cash outflow. Every one of us does cash management. We keep track of how much cash we had in hand before spending and how much we are left with once some expenditure occurs. Based on this we also plan on how much additional amount of cash will be needed to afford coming expenses. As an individual, it does not seem to be difficult, but the level of difficulty increases when business people have to do that, and it is really tricky when it comes to banks. Banks are financial institutions which serve timely and untimely financial needs of their customers in addition to giving other services. From the viewpoint of banks, cash management at Automatic Teller Machines (ATMs) refers to the amount of cash or currency held at the ATM machines any particular time. This money is used to sanction loans, meet customer withdrawal needs etc. Banks need cash in hand or liquidity not only to perform their daily operations smoothly but also have to fulfill untimely needs of their customers. With liquidity, the banks are able to meet financial obligations as they come.

Banks understand this typical behavior of their customers and install ATM machines to give services to their customers. So far, so good, but the problem arises when the bank managers have to manage cash in these machines. There are lots of problems faced by managers in doing this; cash lying in the machines not used by the customers in that area increases carrying cost. This also decreases opportunity cost for the bank which could have been realized by utilizing this unused cash. On the other hand customers wanting cash approach ATM machines anytime when they need it and if the machine fails to dispense the desired cash it leads to customer dis-satisfaction. In worst case, the bank may lose such unsatisfied customers. This means that the bank manager has to be very careful while deciding the cash required at ATMs. For this purpose, he many consider many factors like the area, type of customers, season etc. to take decision of keeping the right amount of cash in ATM machines. There is a need of a method is to decide the optimum amount of cash to be kept in ATMs for

minimizing opportunity costs as well as satisfying the customers uncertain and unplanned need of cash.

The decision of optimized cash refilling in ATM is done manually according to corporate policies and past experience. This process may sometimes lead to poor service or unnecessary cost due to under or over-estimation of cash demand. For this reason, finding the best match between cash requirement and demand fulfillment becomes a crucial decision for bank authorities. Therefore, the purpose for banks is to decide an optimum amount of money that should be placed in ATM to minimize opportunity costs and at the same time to satisfy the customers' untimely and uncertain requirements.

A model based on a neuro-fuzzy approach has been suggested for proactively analysing and forecasting daily cash requirement in ATM assuring prompt cash availability and dispensing service. Parameter selection is performed using neighbourhood mutual information-based algorithm for attribute reduction to find best parameters. Simulation results for ATM cash forecasting show the feasibility and effectiveness of the proposed method. It is seen from table 5 that the increase in training dataset size with chosen parameter values decreases the prediction error.

Table 5. Fuzzy ARTMAP Training Performance

Test Run	Dataset Size	Choice Parameter α	ART_a Vigilance ρ_a	No. of Epochs	No. of Simulations	Performance Accuracy
1	1000	0.001	0.7	5	3	86.00%
2	1200	0.001	0.8	5	3	87.11%
3	1500	0.001	0.95	5	3	89.02%
4	1000	0.01	0.7	5	3	87.20%
5	1200	0.01	0.8	5	3	87.93%
6	1500	0.01	0.95	5	3	91.45%
7	1000	0.1	0.7	3	3	87.80%
8	1200	0.1	0.8	3	3	89.53%
9	1500	0.1	0.95	3	3	92.36%
10	1000	0.1	0.7	5	3	93.00%
11	1200	0.1	0.8	5	3	93.59%
12	1500	0.1	0.95	5	3	94.23%
13	2000	0.1	0.95	5	3	96.12%
14	3000	0.1	0.95	5	3	100%

The experimental results show that with more number of categories, a better is generalization is obtained by the network while lesser number of categories gives less accurate results. When tested on test set of size 800, the network generates total 340 categories with categories with a prediction rate of 96.05%. On test set size 1000, the network generates total 365 ART_a categories giving prediction rate of 97.2%.

Hence, it is observed that increase in training dataset size with chosen parameter values decreases the prediction error. The model is capable of handling voluminous information and is responsive more to vigilance parameter, but not to choice parameter. Further, it is sensitive more to the size of training dataset, but less to the number of input parameters. The time taken to training the network is less than one-third time with selective 7 parameters than with all 13 parameters.

IV. Observations and Discussion

The central objective of this work is to study selective real world problems full of vagueness and to attain the said objective a rigorous study of existing applications of neuro-fuzzy system is performed for choice of real world problems for performing simulations on anticipated neuro-fuzzy models. The neural network faced many difficulties during training affecting the performance in terms of accuracy and response time. In the light of these problems, a lot of observations are made in this work.

Parameter selection techniques are employed before actual experiments are done on the training dataset. The benefits of parameter selection are multi-fold. It may improve the performance of prediction. The algorithms applied may not sometimes scale to the size of full feature set. It allows better understanding of the domain and dependency among the parameters in the domain. It is cheaper and safer to collect a reduced set of predictors.

Another key step is to conduct sensitive analysis on the training data during training to get the choice feature values. Sensitivity analysis have been performed on training data in some of the problems presented to make sure that correct values of the constants affecting the network performance are chosen for conducting the experiment and coming down to conclusion. Experiments have been carried out to perform sensitivity analysis on the key input parameters on the above problems.

- While training the FSVM, its performance is observed on variations in cost and curvature parameters. The sensitivity of the network is tested

on these two parameter values to decide the best parameter value combination to increase the network's prediction accuracy.

- When considering the amount of cash required in ATM, the experiments are performed on ATMs from different areas belonging to a local bank. For selecting the best parameters which can be used in further process, a sensitivity analysis is done on two variables namely neighborhood size and tolerance value.
- The training performance of Fuzzy ARTMAP is assessed by variations in the values of two parameters; choice parameter and vigilance parameter and the sensitivity of network is observed.

It is intricate to identify in advance the duration of neural network training, as it varies from application to application and depends on many factors including the complexity of the problem, number of features under consideration, performance expectation from the system etc. Typically, in supervised learning in neural networks, the training continues till the training error comes down close to zero; which means that the network is trained till its actual output becomes approximately same as the target output. The learning is continued until some pre-specified error level is reached. In notations,

$$e = t - a \tag{1}$$

$$e \le \varepsilon \tag{2}$$

where, $\varepsilon \in [0.001\ 0.01]$ is the error tolerance, t is the target network outcome and a is the actual outcome. In this work, we have taken the error tolerance to be adequately larger to avoid chances of network over-fitting. A 0 tolerance level may increase network learning time and sometimes may render the network to stick to the learnt behavior.

At last, a comparative analysis is carried out which proves novelty of proposed methods in this work. The results of proposed models have been analyzed for their suitability in practical applications by performing comparison with existing work. The methodologies are not only novel in their own areas, but also suits to larger domains. The generalization capability of neural networks makes these models scalable up to some extent, depending on the type of problem. Some of the reasons for selecting the proposed methodologies are:

- The most popular neuro-fuzzy network Adaptive Neuro-Fuzzy Inference System (ANFIS) resembles neural network's layered structure and is easy to understand and implement. ANFIS is applied to predict bankruptcy of a company at any moment in future.
- Fuzzy Support Vector Machines (FSVM) are best suited for applications where the characteristic of non-linear seperability of support vectors can be utilized at its best. For this reason, the same bankruptcy prediction is extended to financially distressed companies with the help of FSVM.
- Fuzzy Probabilistic Neural Networks (FPNN) is easy to implement than a back propagation neural network because of its time consuming training process and hence can be used for performing repetitive task. Considering this fact, a FPNN is set up to forecast the performance of a student knowing his particulars at present moment.
- Fuzzy ARTMAP, a modified and refined form of Fuzzy Adaptive Resonance Theory Networks (FART), is capable of best input-output mapping owing to its architecture. The most complex problem of determining the amount of cash in ATM machines uses Fuzzy ARTMAP and approximately finds out the amount of cash required at any instance of time in future.

In general, fuzzy neural network architecture offers distinct advantages over conventional neural networks like better performance accuracy, supervised and online learning capability and faster convergence rate. A common complexity involved in achieving the desired outcome in all the models is various parameters setting. Although these parameter values typically lie in fixed closed interval, but determining the correct value of these parameters is difficult and sometimes time consuming.

V. Conclusions and Future Work

Neuro-fuzzy networks have shown a great deal of success in their applications in wide range of problem areas. The common problems faced in the models studied are long training periods and sometimes over-fitting. A neuro-fuzzy network is in a way a neural network with multiple layers and with the size of network and complexity of the problem, the limitation of neural networks may increase. The Integration of neural network with fuzzy logic comes up with solution of their individual limitations but the problem of local minima remains the same. Some data pre-processing techniques can be applied on the training data before it is used to train the network. This may possibly reduce the training time and hence the convergence time of the neuro-fuzzy network. Secondly, choosing the right parameter values can play an important role during training. Although this may take some trials, but once the values of these parameters are fixed, the network can give expected performance.

From the view point of business, there are lots of real world problems full of vagueness and uncertainty which need good attention these days. To deal with these problems where decision-making using classical methods fail some hybrid soft computing models can come up. In this view, it is not suggested to abandon all these classical methods at once. Instead, business people can think of giving due attentions to fuzziness in their business by proper utilization of these models.

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