A Literature Review on Recent Advances in Neuro-Fuzzy Applications

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----------**ABSTRACT**----------
Traditional algorithmic approaches are not suitable for solving today's business problems. Neuro-Fuzzy systems have recently become popular and promising choice among researchers in attempt to solve complex problems faced in business. The paper presents a brief review of most recent applications in business aimed at knowing future events in advance specifically employing neuro-fuzzy approach. The neuro-fuzzy systems designed and developed during 2011 and 2014 have been studied with the intention to explore the recent developments. Prominent applications in some wide-spread domains are considered with an outlook of their capabilities in respective domains.

Keywords - Fuzzy logic, Hybrid systems, Neural networks, Traditional methods, Uncertainty

I. INTRODUCTION

In recent years, numerous studies have been carried out which revealed the limitations of traditional methods in dealing with problems of today. The methods currently used in business are somewhere incapable of prediction of future events to act proactively due to vagueness and mass of the data or due to complexity of the problem. Everything cannot be represented precisely due to unavailability of proper information, lack of information or unclear information. It is evident that traditional computing methods are inefficient in such situations. A significant research contribution in finding solution to these problems has made companies to see a gradual shift from traditional methods to advanced systems. The reason behind the motivation is obvious; the common characteristics of business problems like non-linear behavior, high degree of uncertainty, lack of precise knowledge etc. A variety of machine learning techniques are being developed for possible application into various fields to experience intelligent information systems.

The advancement of technology, success of upcoming methods and their acceptance has given way to modified methods in almost all areas. An emerging class of intelligent machines taking place of traditional methods consists of fuzzy logic and neural networks. Fuzzy logic provides a mathematical foundation for dealing with situations full of uncertainties by simulating human perception for understanding linguistic attributes while neural network mimics human beings in the process of learning, thinking and adaptation. A combination of these two techniques called neuro-fuzzy systems has the potential to get the advantages of both leaving behind their limitations. In a hybrid model, neural network learning algorithms are fused with fuzzy reasoning of fuzzy logic. Each of the components plays their own role; neural network determine the values of parameters while if-then rules are handled by fuzzy logic. A fuzzy inference system uses human expertise by storing required knowledge in its rule-base, and then performs fuzzy reasoning on the input to infer the overall output value.

Fuzzy logic and neural networks complement each other in developing intelligent systems. Neural networks form low-level computational structures and can deal with raw data while, fuzzy logic sits on a higher level and uses linguistic information. Looking from the other viewpoint, fuzzy systems lack the ability to learn and cannot adjust to a new environment, but neural networks can learn and generalize. A general problem with neural networks is that they are black box with number of hidden layers whose operation is opaque to user. Integrated together, the resultant neuro-fuzzy system can perform parallel computation and learn like neural networks and can represent human-like knowledge with explanation abilities of fuzzy systems making the overall system more transparent.

Researchers from varied domains have attempted and relied on the use of hybrid neural network and fuzzy logic approach. A neuro-fuzzy system has input and output layers, and hidden layers representing membership functions and fuzzy rules, which learns to solve problems full of uncertainty. It is not possible to include all the applications on neuro-fuzzy hybridization, so we restrict the discussion to domains like education and banking & finance where the day to day decisions are affected by customer behavior.

II. Existing Applications

There are numerous interesting applications that aim to solve complexity of business problems. The advent of technology has opened doors for Artificial Neural Networks (ANN) which have tendency to simplify the programming

effort and algorithm design used in conventional methods. Systems built on Fuzzy Logic (FL) have the capability to deal with uncertainty in the environment in which any business flourishes. There are numerous application areas in which ANN and FL have been successfully applied whether separately or complementing each other's strengths. A combined neuro-fuzzy approach has seen great inclination recently from researchers working in various domains. A detailed study of existing work in various areas using soft computing methodologies specifically focusing on neural networks and fuzzy logic can be referred in [1].

In banking and finance domain, Zanganeh [2] demonstrates effectiveness of ANFIS in bankruptcy prediction on a data set consisting of financial ratios of bankrupt and non-bankrupt firms in Tehran. They used two procedures for selecting predictive variables; without any feature selection method and with T-statistic feature selection method. The analysis of empirical results indicates that ANFIS model outperforms Logistic Regression. In another study Giovanis [3] applied two approaches for prediction of economic recession or expansion periods in USA; first including Logit and Probit models while the second utilizing Adaptive Neuro-Fuzzy Inference System (ANFIS) with Gaussian and generalized bell membership functions. A data set consisting of samples from period 1950-2006 shows that the ANFIS model outperforms the Logit and Probit model and hence indicates that neuro-fuzzy model provides a better and more reliable signs of financial crisis.

To predicting bankruptcy, Arora & Saini [4] presented an ANFIS model utilizing time series. According to them, all the stakeholders get affected by the financial status of their company. Analysis of financial ratios can give them some idea of current financial stand of the company, but cannot reveal what would be its status in future. Their model considers a set of historical data in the form of financial ratios to calculate the corresponding Z scores and the prediction of Z score is done for future time period. This can predict whether the company is going to be bankrupt in coming years or not. This work was further refined in another model proposed by Arora & Saini [5] which considered financial distressed companies to predict their bankruptcy status in future. There model utilized Independent Component Analysis (ICA) to choose input parameters independent of each other. The initial dataset consisted of 10 financial ratios while ICA returned 5 ratios. The dataset formed from these chosen ratios formed actual data for training Fuzzy Support Vector Machines (FSVM). They carried out tuning on various factors like kernel function, cost and curvature of curve for determining the right choice of values. A comparative analysis of FSVM with ANFIS proved better clustering capability by FSVM. Chen [6] adopted particle swarm optimization technique to obtain appropriate parameter settings for subtractive clustering by integrating the Adaptive Network based Fuzzy Inference System (ANFIS) model to predict business failures. Experiments conducted on companies listed on the Taiwan Stock Exchange Corporation (TSEC) shows that the model is superior to other models, with lower mean absolute percentage error and root mean squared error. Their conclusion indicates their proposed hybrid approach to provide better results in predicting potential financial distress of a company. According to Behbood [7] a precise financial early warning model is desirable for decision makers and regulators in any organization belonging to financial industry. They presented a model for financial warning combining fuzzy inference system with the learning ability of neural network to predict financial status of an organization with Fuzzy Case-Based Reasoning (FCBR). An adaptive fuzzy rule base is generated to predict financial status of target case. If the case is predicted to fail, the FCBR is used to find similar survived cases. The model facilitates decision maker by providing financial decisions to change particular features as company goals in upcoming year to avoid future financial distress.

From the viewpoint of Fang [8] all financial institutions use more traditional financial analysis as well as external ratings to measure its risk. Their study involves the use of Adaptive Network-Based Fuzzy Inference System (ANFIS) prediction of the crisis of corporate finance. They applied factor analysis of the screening variables, and compared ANFIS with ANN. The results show ANFIS correctness rate of 93.94% which is significantly higher than ANN accuracy rate of 89.49% and proved the effectiveness of ANFIS in prediction of corporate financial crisis as compared to ANN. Edward Altman [9] presented a model for bankruptcy prediction also known as the Altman's Model in 1968 using five financial ratios. Later in 1980, Ohlson [10] raised questions on the restrictive statistical requirements of the model. To overcome the limitations, he employed logistic regression to predict company failure. A comparison of two models by Altman and Ohlson to predict bankruptcy of companies [11] is conducted on the dataset comprising Iranian listed companies. The Altman model is found to give better results and the model is recommended to investors to predict bankruptcy of companies.

It is important for any business to understand the dynamic behavior of customers which is a challenging task. In an interesting work, cash management in Automatic Teller Machines (ATM) is studied with the intention of maintaining an optimized amount of cash in a bank ATM. It is found that the demand for cash fluctuates due to change in customer's behavior, preferences, seasonality, time etc. An application of fuzzy ARTMAP Network is suggested for proactively analyzing and forecasting daily cash requirement in ATM assuring prompt cash availability and dispensing service [12].

Continuing in the same direction and looking at the current trends in education, it was felt from the institution's viewpoint that an early prediction about academic capabilities of a student can lend a hand in identifying his inabilities, providing scope for improvement, and thereby locking in the student [13]. The authors brought into light the need of a model which can play a significant role in academics by providing an insight to the teacher to better plan the lectures depending on student's level. Their results

demonstrate that a model based on Fuzzy Probabilistic Neural Network can help the teacher to analyze the behavior and understanding level of a student to take corrective steps in class.

In their work, Iraji [14] designed an intelligent system to separate and classify students according to their learning and performance. The classification is done through two methods viz. LVQ networks and ANFIS method. Both the methods consider student's learning factor for the classification criteria. It is observed that ANFIS outperforms LVQ method. The aim of classifying students is to identify scholarship students and to spot weak students or likely to fail students so that proper tutoring resources can be allotted to them. The classification of students may be helpful in planning strategic programs for improving students' performance. Similar concept can be found in methodology for prediction of students' performances and classification proposed by Inyang [15]. They experienced that graduates with less grades face difficulties in getting employment and hence the institute needs to identify and group these students at an early stage during the studies so that a performance improvement plan can be developed for them. Their methodology is based on combination of FCM, k-means algorithms and ANFIS. Authors presented reasons for choice of each technique and tried to present a hybrid approach which shows satisfactory results to be suitable for the prediction and clustering of students based on their performance level.

In view of Do & Chen [16] a proper classification of students based on their academic performance in previous exam can help in admission decisions and educational services at educational institutes. Giving admission to unsuitable candidate may affect quality level of the institute. They have the same viewpoint as [13] that an early prediction may give teachers a chance to plan suitable teaching actions for each group of students. They concluded from the experiments that their neuro-fuzzy model can be used for classifying students into groups based on their expected academic performance. They also conducted comparison of neuro-fuzzy approach with result of support vector machine, Naive Bayes, neural network, and decision tree approaches. The comparative analysis indicate that the neuro-fuzzy approach perform better than others. The model achieved an accuracy of over 90% and claimed to be acceptable as a classifier of students' academic performance.

Considering similar parameters Catherine et al. [17] designed a neuro-fuzzy based model to determine the learners' learning preference. They used neuro-fuzzy expert reasoning to evaluate learner learning capability relative to the learning concepts processes and stored in the learner profile during the interaction of the learners with the system. It is observed that the model could identify and classify 96% into their respective learning preferences while 4% could not be classified correctly due to inconsistent input responses pattern from the learners. The model is expected to be used by the instructor to advice the learner on how to develop weak learning style.

In a neuro-fuzzy actuator-indicator integration model [18], a technique for capturing teacher's knowledge to monitor learners' activities in Neuro-fuzzy model is presented. This is essentially done for enabling online automatic monitoring. The model provided competence assessment for taking decisions like a teacher. For achieving the desired result, the authors considered a case study involving tracking and measuring quality of learners. The model is expected to solve the problems of timeliness, accuracy and reliance on the commitment of the human teacher associated with visualization approaches.

It is argued that problems in science and engineering can be converted to a set of differential equations [19]. Although there are various numerical methods like finite difference method, finite-element method, finite volume method and the boundary element method etc. which can be used to solve differential equations, but the approximation properties of neural networks are best suited to solve differential equations to a good degree of precision. The dynamic behavior and approximation capabilities of ANFIS gave them direction to solve differential equations and hence the business problems. They present ANFIS to solve differential equations. The accuracy of their method was examined by solving first-order and second-order differential equations.

A lot of researchers are busy in exploring the potency of neuro-fuzzy networks. There cannot be any boundary for the possibility of integration of these two techniques neither to any application type nor to a domain. There is no field around us which has remained untouched from uncertainty. The learning capability of neural network and capability of fuzzy logic to deal with vagueness lends a hand in accepting the hybrid neuro-fuzzy methodology as one of the best alternative for solution of problems in these fields. The future will see most promising applications of neuro-fuzzy techniques in almost all domains.

III. Performance analysis

A performance analysis can better depict the contribution using neuro-fuzzy systems. Table 1 provides a concise summary of the applications discussed above.

Table 1: Recent Neuro-Fuzzy Applications

Contributor	Technique	Parameters Considered	Findings
(Zanganeh) [2]	ANFIS with and without feature selection	EBIT/Total asset, Net income/total assets, Working capital/total assets, Sales/total assets, Retained earning/total assets, Current assets/current Debts	ANFIS model outperforms Logistic Regression with prediction accuracy of 96.27%
(Giovanis) [3]	Logit and Probit models ANFIS	Gross domestic product growth rate (GDP), Unemployment rate	ANFIS model outperforms the Logit and Probit model
(Arora & Saini) [4]	ANFIS model utilizing time series	Working Capital/Total Assets Retained Earnings/Total Assets EBIT/Total Assets Market Value of Equity/Book Value of Total Debt Sales/Total Assets	ANFIS model can predict bankruptcy status at any time in future with prediction error in range 0.8506 to 0.3204
(Arora & Saini) [5]	Fuzzy Support Vector Machines with ICA	Quick Ratio, Current Ratio, EBIT/Total Assets, Total Assets Turnover Ratio, Retained Earning/Total Sales, Return on Capital Employed, Current Assets/Total Sales, Inventory Turnover Ratio, Debt equity Ratio, Operating profit Margin	FSVM model can predict bankruptcy of financially distressed companies with an accuracy of 93.12% on unseen inputs
(Chen) [6]	ANFIS model with PSO	Current ratio, Acid-test ratio, Inventory to total assets ratio, Current assets to total assets, Debt to equity ratio	Since RMSE falls from 0.1638 to 0.1001, model can efficiently handle large amounts of data and reduce the prediction error rate.
(Behbood) [7]	Fuzzy Case-Based Reasoning	Financial ratios	The model is expected to go beyond prediction by providing prediction-based decision making component to recommend solutions for decision makers
(Fang) [8]	ANFIS with factor analysis	Current ratio, Quick ratio, Cash flow ratio, Net income to total assets ratio, Net income to equity, Inventory turnover, Accounts receivable turnover, Debt ratio, Debt to equity ratio	ANFIS correctness rate of 93.94% is better than ANN accuracy rate of 89.49%
(Arora & Saini) [12]	Fuzzy ARTMAP	Location, Area, Reachability, Locality, Population, Customers, Customer's age group, No. of account holders, Account holder type, Customer's family size, Seasonality,	Prediction rate of 96.05% makes the model suitable for daily replenishment of cash

		Security threat	
(Arora & Saini) [13]	Fuzzy Probabilistic Neural Network	Merit, Interest, Belief, Study Behavior, Class Behavior, Family Background	Model is efficient in prediction with overall error 2.6667 giving 98.56% accuracy in expected results
(Iraji) [14]	LVQ networks and ANFIS method	Age, Family, Previous knowledge, Educational psychology, Instruction, Learning style, Teaching material	ANFIS outperforms LVQ method with root mean square error 0.1348 over 0.2374
(Inyang) [15]	FCM, k-means algorithms and ANFIS	Grade Point Average, Cumulative Grade Point Average	RMSE of the model is 0.2819 which makes it suitable for the prediction and clustering of students.
(Do & Chen) [16]	Neuro-fuzzy model	Entrance examination score, Gender Average score of graduation examination, Time between graduation and getting admission, Location of student's high school, Type of high school attended	model achieved an accuracy of over 90% Better than support vector machine, Naive Bayes, neural network, and decision tree approaches
(Catherine et al.) [17]	Neuro-fuzzy based model	Study level, Review study level, Collaborative level, Assignments, Final exam	Correct classification upto 97%
(Omidiora) [18]	Neuro-fuzzy actuator-indicator integration model	Total time spent reading, Content completion status, Attention level, Diagnosis assessment remarks	Simulated model is expected to automatically monitor student activities

There are many ways of getting advantage of hybrid neuro-fuzzy technology combined with other methods, but as an obvious observation it can be noted from table 1 that Adaptive Neuro-Fuzzy Inference System (ANFIS) is the most popular choice among the researchers due to its accuracy in prediction and classification. Besides these prominent results, this fact cannot be ignored that other neural networks are also being tried for their possible applications in various domains in combination with fuzzy logic. A variety of neural network architectures are available which can be possibly merged with fuzzy logic to take their best advantage.

IV. Concluding remarks

Almost all business problems suffer from vagueness which demands proper attention from business leaders. To remain in the competition, business leaders need some tools which can assist them in decision making. Recently a variety of methodologies have been proposed expected to give promising results in their respective areas. Many research papers have been published showing comparison of two or more methods on existing work in various areas. Moreover, hybridization of many approaches has shown satisfactory results in different areas. The paper has attempted to review current advancements in business using neuro-fuzzy hybridized approach. To sum up, a comprehensive review of applications combining neural network and fuzzy logic in business have been presented, by discussing some studies published between 2011 and early 2014.

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