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A NOVEL INDEPENDENT COMPONENT ANALYSIS APPROACH FOR BANKRUPTCY PREDICTION USING NEURO-FUZZY NETWORKS

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ABSTRACT

The aim of this research is to model the dependency of enterprises on their financial ratios for predicting bankruptcy using artificial neural networks combined with fuzzy logic. The data used in this study has been extracted from the financial reports of ongoing and failed enterprises for past five years. Independent Component Analysis has been applied on the input dataset comprising of financial ratios to choose the most significant ratios to be considered as input to the neuro-fuzzy network. Around 2012 subsets of input vectors, each containing five variables were used for training and around 51 were used for testing the network's performance. In this way the model predicts the bankruptcy status of the enterprises with minimal training errors. A rule-base consisting of fuzzy rules of the network is formed, which is used for the linguistic diagnosis of failure or financial problems of the enterprises.

The proposed model can be used by banks as a loan approval system. In other words, 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.

KEYWORDS

Bankruptcy, Financial ratios, Independent Component Analysis, Neuro-fuzzy Network, Prediction.

INTRODUCTION

Bankruptcy prediction has been an active research field in finance since 40 years. The problem of timely and correctly predicting bankruptcy is of great importance for financial institutions. A number of groups including investors, auditors, creditors and employees are affected by corporate failure and hence are interested in accurate forecasts regarding the financial strength of companies. Prediction of bankruptcy has dual benefits. If bankruptcy can be predicted with sensible accuracy well in advance, it not only can help the companies to take preventive measures, but also may help bank authorities for approving/disapproving loans. Once the loan is approved, one of the important issues for the bank is that whether the debtor company will become bankrupt or not. This again gives rise to the need of a system with an early warning facility to predict the chances of bankruptcy for the borrowing company.

Bankruptcy for a company is a final declaration of its inability to sustain current operations given its current debt obligations. According to financial theories, a financial ratio is a ratio of chosen numerical quantities picked up from the financial statements of a company. A large number of standardized financial ratios are utilized for the assessment of the financial state of a company. The financial ratios are applied by the probable and present shareholders of a company, the creditors of a company and the managers of a company. Bankruptcy prediction may help the investors avoid huge economic loss. Financial ratios are also used by security analysts for the purpose of comparison between the positives and negatives of different firms. The main impact of such research is in bank lending. Banks need to predict the possibility of default of a potential counterparty before they extend a loan.

Hybrid neural networks have been applied by many researchers in business classification problems. In this paper, an Adaptive Network-based Fuzzy Inference System (ANFIS) proposed by Roger Jang [7] is used to predict the possibility of business failure. The rest of the paper is organized as follows. Section II reviews prior literature on bankruptcy and Neural Networks. Section III explains data and sample selection. Section IV presents the methodology used and discusses test results. Finally, Section V summarizes findings and conclusion of this study.

A REVIEW OF BANKRUPTCY PREDICTION

The first study in this area was done by Smith and Winakor in the Great Depression era 1935, followed by Merwin 1942 who showed that failing firms exhibit significantly different ratios than successful firms do. The most acceptable model of bankruptcy prediction, the Z-score model developed by Altman, came in the late 60's [2]. The five variable Z-score model using multiple discrimination analysis showed very strong predictive power. Since mid 1980's, neural networks have become the dominant research area in artificial intelligence and researchers have actively applied neural networks to classification problems including bankruptcy prediction. Shin & Lee, 2002 [7], apply a genetic algorithm for extracting meaningful rules for bankruptcy prediction. In their study, they also refer to numerous other artificial applications in bankruptcy. They use nine financial ratios to describe each of their 528 manufacturing cases, but the genetic algorithm based model for prediction uses finally only five of them. Accuracy ranges between 76 and 85% for this promising technique. Kim & Han, 2003, also use genetic algorithm based data mining for discovering bankruptcy decision rules from experts' qualitative decisions. The authors used 772 Korean cases to define six qualitative factors for describing the cases.

Tam and Kiang [5], [6] considered the problem of bank failure prediction. They compared between several methods: MDA, LR, K-nearest neighbor, ID3 classification algorithm, single-layer network, and multilayer network. For the case of one-year-ahead, the multilayer network was the best, while for the case of two-year-ahead, LR was the best. When they used a leave-one-out procedure instead of a hold-out sample, the multilayer network was the clear winner. KNN and ID3 were almost always inferior to the other methods. Kerling and Poddig [8] compared NN with MDA for a database of French firms for a three-year-ahead forecast. The NN achieved prediction accuracy in the range of 85.3–87.7% compared to 85.7% for MDA. Back et al. [3] propose the use of genetic algorithms for input selection, to be used in conjunction with multilayer networks. They applied their method to data covering the periods one to three years before the bankruptcy, where it obtains significant improvement over MDA.

Fan and Palani swami [1] propose the use of support vector machines (SVMs) for predicting bankruptcies among Australian firms, and compared it with NN, MDA and learning vector quantization (LVQ). SVM obtained the best results 70.35%–70.90% accuracy depending on the number of inputs. Yang et al. [10] used probabilistic NNs (PNNs), which essentially implement the Bayes classification rule. They tested it on firms in the oil sector. The results were mixed, PNN tied with the multilayer networks, but with a particular preprocessing step MDA was the best.

Salcedo-Salcedo-Sanz et al. [9], 2005 proposed genetic programming for the prediction of possible bankruptcy of the insurance companies. The sample comprises of 72 Spanish insurance firms equally balanced between bankrupt and non-bankrupt ones, and 21 financial ratios are used to describe the data. Not all the ratios are used by the genetic programming approach to form the decision model, while accuracy is promising. Comparisons are made with rough sets approaches.

BANKRUPTCY DATA DESCRIPTION

The data used in this study comprise of the financial ratios of various enterprises which consist of both failed & financially distressed firms and non-failed & financially contented firms. Independent Component Analysis is carried out on the 10 ratios and as a result around 5 were selected to be used as input to the next stage. The meaning of input variables is shown in table 1.

Table 1: Initial Input Ratios List

Ratio	Meaning
R 1	Quick Ratio
R 2	Current Ratio
R 3	EBIT/Total Assets
R 4	Total Assets Turnover Ratio
R 5	Retained Earning/Total Sales
R 6	Return on Capital Employed
R 7	Current Assets/Total Sales
R 8	Inventory Turnover Ratio
R 9	Debt equity Ratio
R 10	Operating profit Margin

Through the research of many years neural network has been found to perform well in business classifications including bankruptcy prediction but it fails to explain the relationship among the input variables. On the other hand, in reality all the inputs to the neural network cannot be always measured precisely. Hence, an approach consisting of neural network with fuzzy inputs is used here to solve the problem in hand.

INDEPENDENT COMPONENT ANALYSIS

The goal of ICA is to recover independent sources by de-correlating inputs and thereby reducing higher-order statistical dependencies, attempting to make inputs as independent as possible. ICA uses a preprocessing technique called whitening which linearly transforms vector X to vector $V = UX$ such that its elements v_i are mutually uncorrelated and have unit variance. Thus, the correlation matrix of V equals unity. This not only reduces the dimensionality of the data by finding out independent components from set of input vectors but also has the effect of reducing noise. Fig. 1 shows the graphical representation of input dataset used for ICA:

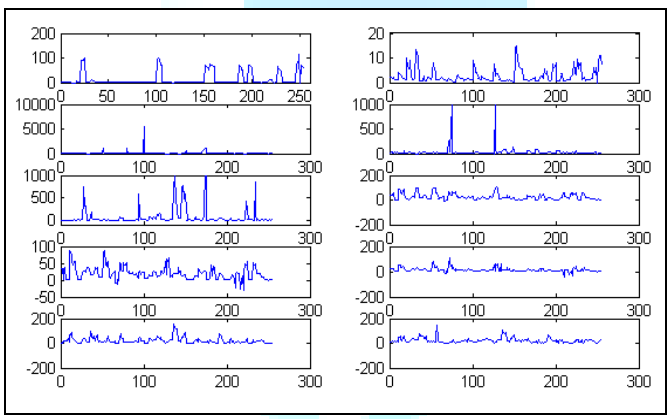


Fig. 1. Input Ratio Dataset for ICA

As seen from fig. 2, set of 5 ratios namely EBIT/Total Assets, Total Assets Turnover Ratio, Retained Earning/Total Sales, Return on Capital Employed, Debt equity Ratio are found to significantly vary independent of other ratios and hence are ready to be taken as input to ANFIS.

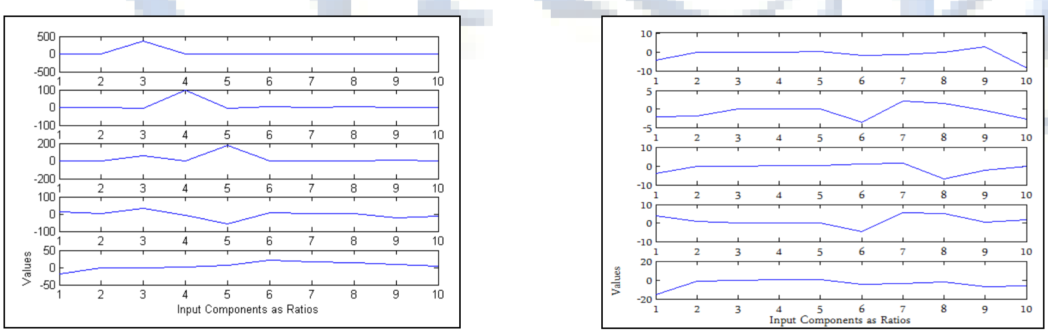


Fig. 2. (a) Filtered Ratio data for First 5 Components **Fig. 2. (b) Filtered Ratio data for Next 5 Components**

ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM

Hybrid systems have proved to provide effectiveness in a wide variety of real world problems. While neural networks are good at recognizing patterns, they are not good at explaining how they reach their decisions. Fuzzy logic systems, which can reason with imprecise information, are good at explaining their decisions but they cannot automatically acquire the rules they use to make those decisions. These limitations have been a central driving force behind the creation of intelligent hybrid systems where two or more techniques are combined in a manner that overcomes the limitations of individual techniques.

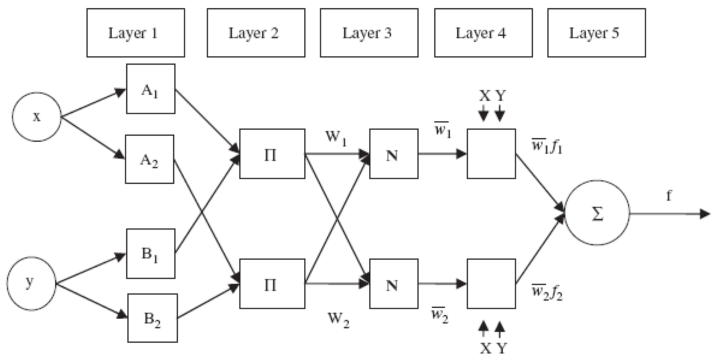


Fig. 3. The Architecture of ANFIS Network

To enable a system to deal with cognitive uncertainties in a manner more like humans, the concept of fuzzy logic is incorporated into the neural networks. As suggested by Roger Jang in 1993, Adaptive Neuro-Fuzzy Inference System can serve as a basis for constructing a set of if-then rules with proper membership functions to generate input-output pairs. A basic fuzzy inference system consists of 5 layers as shown in fig. 3.

The node in the i^{th} position of the k^{th} layer is denoted as $O_{k,i}$, and the node functions in the same layer are of the same function family as described below:

Layer 1: This layer is the input layer, and every node i in this layer is a square node with a node function. $O_{1,i}$ is the membership function of A_i , and it specifies the degree to which the given x satisfies the quantifier A_i . Usually, we select the bell-shaped membership function as the input membership function, with maximum equal to 1 and minimum equal to 0.

$$O_{1,i} = \mu A_i(x) \quad for\ i = 1, 2... \tag{1}$$

where,

$$\mu A_i(x) = \frac{1}{1 + \left[\left(\frac{x - c_i}{a_i}\right)^2\right]^{bi}}$$

where a_i , b_i and c_i are the parameters, b is a positive value and c denotes the center of the curve.

Layer 2: Every node in this layer is a square node labeled P which multiplies the incoming signals and sends the product out by eq (2):

$$O_{2,i} = W_i = \mu A_i(x) \times \mu B_i(y) \quad for\ i = 1,2,... \tag{2}$$

Layer 3: Every node in this layer is a square node labeled N. The i^{th} node calculates the ratio of the i^{th} rule's firing strength to the sum of all rules' firing strengths by the eq (3). Output of this layer can be called normalized firing strengths.

$$O_{3,i} = \bar{W}_i = \frac{W_i}{W_1 + W_2} \qquad for\ i = 1,2... \tag{3}$$

Layer 4: Every node i in this layer is a square node with a node function as seen from eq (4). Parameters in this layer will be referred to as consequent parameters.

$$O_{4,i} = \bar{W}_i f_i = \bar{W}_i \left(p_i + q_i + r_i \right) \tag{4}$$

where p_i , q_i and r_i are the parameters.

Layer 5: The single node in this layer is a circle node labeled P that computes the overall output as the summation of all incoming signals refer eq (5).

$$O_{5,i} = \sum \bar{W}_i f_i = \frac{\sum \bar{W}_i f}{\sum W_i} \tag{5}$$

EXPERIMENTS AND RESULTS

The input ratio data is divided into two sets using the 80-20 rule, one for training data to make the model ready and test data to check the validity of the model. Validation data is used to test the data not utilized to develop the model. Initially the input variables were composed of 10 financial ratios of the last 5 years for training and testing. Independent Component Analysis has been applied on these ratios to choose the most appropriate ratios to be considered as input to the neuro-fuzzy network. Fuzzy logic Toolbox of MATLAB is used develop the ANFIS model with 5 inputs and single output as shown in fig.4. Membership function 'gbell' is selected because of their smoothness and concise notation and these curves have the advantage of being smooth and non-zero at all points.

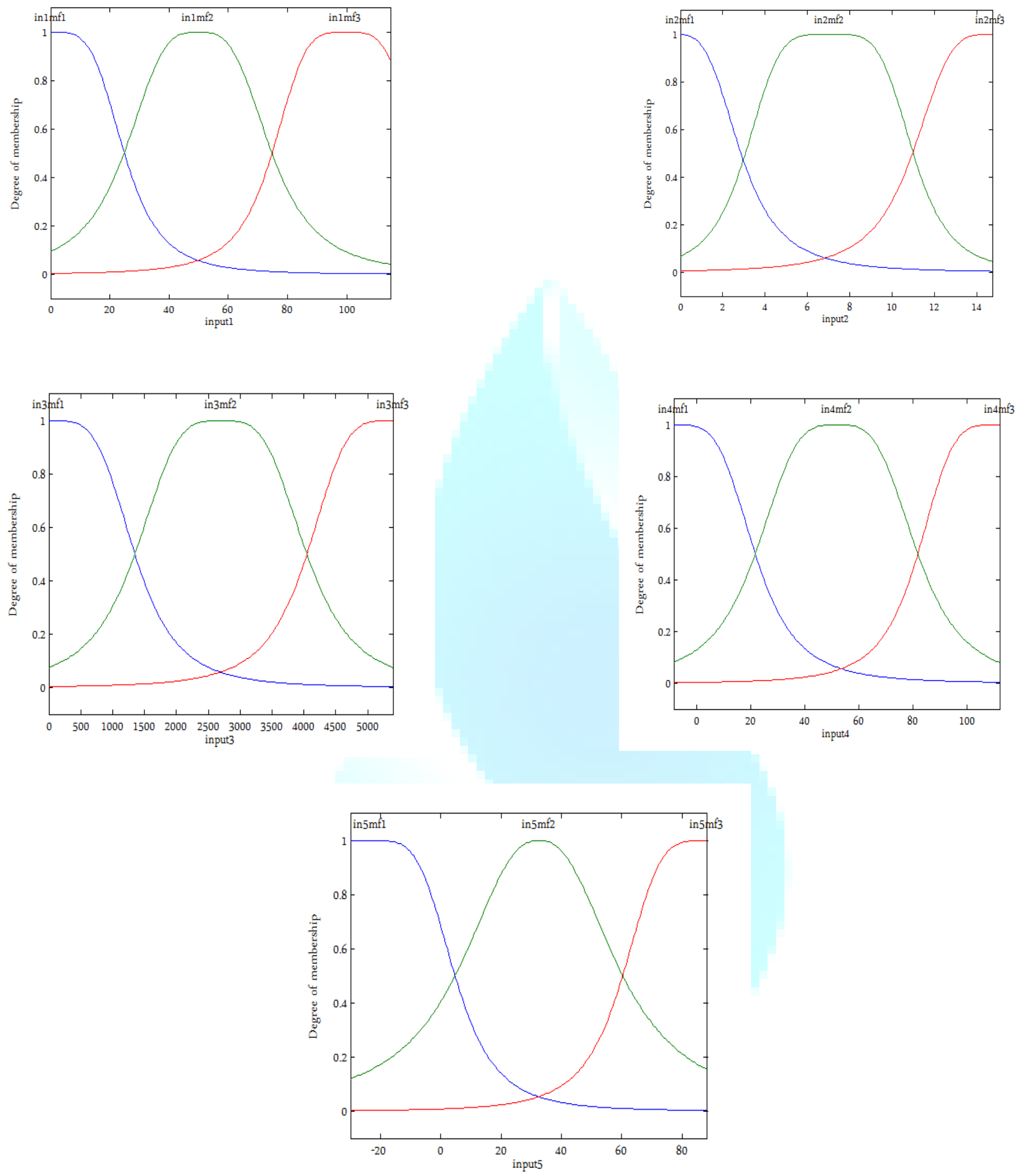
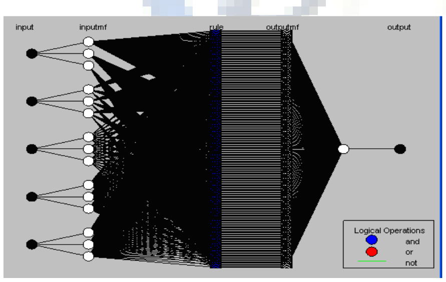


Fig. 4. Input Membership Function for Training Data

MATLAB has been used to model the Bankruptcy prediction and the corresponding five layered ANFIS structure is shown in fig. 5(a). The output is either 1 or 0 to depict whether the firm under consideration is going to be bankrupt or not.



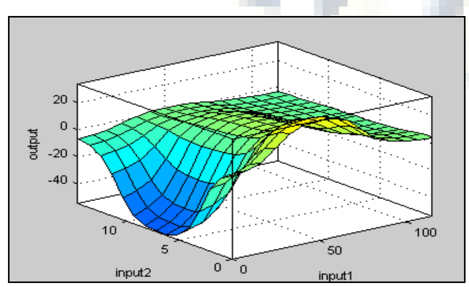


Fig. 5. (a) ANFIS Structure **Fig. 5. (b) Error Surface for ANFIS**

Fig. 5(b) shows the non-linear error surface of Sugeno fuzzy model. The fuzzy inference system model converges either when the stopping criterion is reached to forecast T (t+1) for the target testing data set or the RMSE value is calculated in testing data sets using the formula:

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} \left| actual(t) - forecast(t) \right|^2}{n}}$$

CONCLUSION

The model has proposed a new line of predictive methodology considering various factors as determinants and causes of bankruptcy of a firm. A neuro-fuzzy network is provided 5 inputs with a set of rules to predict the nature of the firm. The proposed model of is new in financial science. It differs from both, traditional MDA and Logit models and more recent simple neuro-fuzzy models in combination with ICA. Evolutionary neural network-based methodologies have been used by many authors, in a variety of application domains with diverse complexity and characteristics, including but not limited to, financial decision support, credit risk management, medical decision making and modeling of fault diagnosis in engineering applications. The application of ANFIS is found to be much more efficient and less complicated as compared to other techniques. The non-linear nature of financial figures can be reasonably handled in the proposed model. ANFIS shows good learning and predicting capabilities while dealing effectively with uncertainty. Hence such a model can be used by bankers, lenders and other stakeholders of the enterprises to predict the enterprise's bankruptcy and thereby can be helpful in lending decisions.

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