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Predicting Financial Statement Fraud Using Fuzzy Neural Networks

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ABSTRACT

Fraud is a common phenomenon in business, and according to Section 24 of the Iranian Auditing Standards, it is the fraudulent act of one or more managers, employees, or third parties to derive unfair advantage and any intentional or unlawful conduct. Financial statements are a means of transmitting confidential management information about the financial position of a company to shareholders and other stakeholders. In this paper, by reviewing the literature, 6 indicators of current ratio, debt ratio, inventory turnover ratio, sales growth index, total asset turnover ratio, and capital return ratio as input and detection of financial fraud as output are considered for the fuzzy neural network. The database was compiled for 10 companies in the period from 2010 to 2018 after clearing and normalizing qualitatively between 1 to 5 discrete numbers with very low or very high meanings, respectively. The fuzzy neural network model with 161 nodes, 448 linear parameters, 36 nonlinear parameters, and 64 fuzzy laws with two methods of accuracy approximation of mean squared error and root mean squared error has been set to zero and 0.0000001 respectively. This neural network can be used for prediction.

1 Introduction

Fraud is a common phenomenon in business, and according to Section 24 of the Iranian Auditing Standards, it is the fraudulent act of one or more managers, employees, or third parties to derive unfair advantage and any intentional or unlawful conduct. Therefore, prevention by detecting significant frauds in the financial statements has always been the focus of the attention of investors, legislators, regulators, managers, and auditors [1]. By increasing the use of modern banking systems and the number of banking transactions, financial abuse and fraud in these transactions, have become more and more prevalent. These abuses not only result in a loss of large financial resources, which leads to a loss of customer confidence in modern banking systems, but it also reduces the effectiveness of those systems in the optimal management of capital and financial transactions [2]. Financial statements are a means of transmitting confidential management information about the financial position of a company to shareholders and other stakeholders [3, 4]. Therefore, it is possible for the owners to execute the contracts between the executives and themselves regardless of the precise nature of these contracts since the transparency of the financial statements is very important and necessary as present

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and future documents [5]. With the development of new technologies, many ways were opened for fraudsters to commit criminal acts. Creating a new information system, in addition to all its advantages and benefits, may give criminals more opportunities to commit fraud [6]. After performing the audit process, the auditor practices content methods, some of which are specifically related to fraud detection. Data mining on company data and earnings databases and other customer databases will be important as an example of analytical methods related to fraud [1]. In recent years, the use of data mining techniques in financial statement auditing has increased, a set of data mining techniques used include support vector machines, social networks, genesis program, neural networks [7]. By utilizing audit techniques, auditors can easily detect the managerial frauds occurring in organizations and thus manage their affairs better. The neural network is one of the categories of dynamic systems that transmits the knowledge behind the data to the network structure by processing the experimental data. Neural networks provide a combination of computational power and flexibility of artificial intelligence while maintaining simplicity and efficiency [8]. In this study, fuzzy neural networks are used to predict fraud in financial statements, because to predict fraud, it is necessary to create a model that is possible by a fuzzy inference system and, along with the use of human knowledge and the information available in the implementation of this model, the artificial neural networks should be used. As a result, both methods should be used. According to studies, the hybrid neural and fuzzy networks have not been used so far to predict fraud. So, this study is innovative in terms of methodology, but the error rate of this method should be compared to other methods.

2 Literature review

Bankruptcy, fraud, and corporate failure have always been a complex issue. In today's world, unlimited human tendencies are set against limited economic resources. The rise and fall of any phenomenon are rooted in the real and logical needs of human societies. The emergence of a fraud audit in the field of professional services also cannot be excluded from this rule. In the present era, technological advances and widespread changes in the business environment have led to an increasing acceleration in the economy, and due to the increasing competition of institutions, the expected earnings are also limited. Therefore, the incidence of fraud is increasing day by day [9]. Cheating is any deliberate act, deletion, or omission planned to deceive or fraud others and cause its victims to suffer losses and its actors and perpetrators gain benefits. All people in society, regardless of culture or religion or any other attribute, are subject to the temptation to commit fraud [10]. Patel et al. [11] examined "the random forest classifiers" for detecting corporate financial statement fraud. They attempted to discover 42 different modeling methods to detect financial statement fraud. Then, the trained model was used to test the validity of the test dataset. The random forest method solves and selects the best accuracy. Here, the modified random forest model is improved with accuracy. Lin et al. [12] studied fraud detection in financial statements The purpose of this study was to evaluate all aspects of the fraud triangle using data mining techniques as well as applying general and available information for proxy variables to evaluate characteristics such as pressure/motivation, opportunity, and attitude/logic based on the findings of preliminary studies in this area as well as the statement of accounting standards.
Mofarreh [13] studied the use of data mining techniques to detect fraud in financial statements. In this study, data mining techniques were used to discover, identify, and investigate factors associated with fraud in financial statements. Abouzari Khoie and Hatamloo [14] investigated the application of a cuckoo optimization algorithm in solving different optimization problems. In this study, first, a general explanation of this algorithm is presented and then the problems solved by this algorithm are ex-

amined and reviewed. Sharma and Panigrahi [15] studied the detection of fraud in financial systems based on data mining methods. In this study, the application of data mining methods to detect fraud in financial systems has been studied comprehensively, and a framework has been presented for its detection-based data mining methods. Zarin Ghalami [16] studied the use of data mining to detect fraud in credit card transactions in Automated teller machine (ATM). The results also show that the Bayesian method is better than other methods in terms of speed and KNN, mean, decision tree, and neural network are at the next ranks, respectively. Also, in terms of accuracy in detecting fraud, the Bayesian method, neural network, and decision tree are ranked first, second, and third, respectively.

3 Solution Method

This is an applied study in terms of the purpose-based classification. Also, methodologically this is an analytical study, because, all the theories, laws, principles, and techniques that detect fraud and corruption of financial statements using a fuzzy neural network, are used to solve executive problems [17]. Artificial neural networks (ANNs) are intelligent computing systems, and their main advantages are high speed and optimal accuracy in predicting complex variables with linear and nonlinear mapping[17]. The artificial neural network is one of the computational methods that by the learning process and using simple processors called neurons, provides a mapping between the input space (input layer) and the desired space (output layer) by understanding the intrinsic relationships between the data. In artificial neural networks, a structure similar to the biological structure of the human brain and the body network is designed. Like human beings, this structure has the power to learn, to generalize, and to make decisions. The layer or hidden layers process the information received from the input layer and provide it to the output layer. Each network is trained by receiving examples [17].

Training is a process that ultimately leads to learning (Fig. 1). Network learning is done when the communication weights between the layers change so that the difference between the predicted and calculated values is acceptable [17]. By achieving these conditions, the learning process is realized. These weights express memory and network knowledge. A trained neural network can be used to predict outputs corresponding to the new data set. T Khanna and J E Day Hoff suggest that the high speed of processing and flexibility against unwanted errors are the features of the artificial neural network [18, 19].

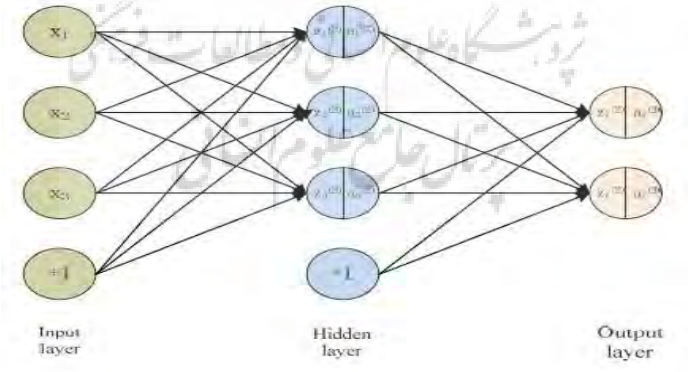

Fig. 1: Back Propagation (Artificial neural network) architecture Fuzzy logic

In general, a fuzzy system as shown in Fig. 2 comprises fuzzification, fuzzy rule-foundation, fuzzy and non-fuzzy output engine processes. In fuzzification, each component of the input information becomes a membership degree. Artificial neural networks are commonly used to optimize fuzzy

membership functions [18, 19]. Most papers use methods whose data are fuzzy, but in this study we use a method called the fuzzy-neural adaptive inference system (ANFIS), which is described below.

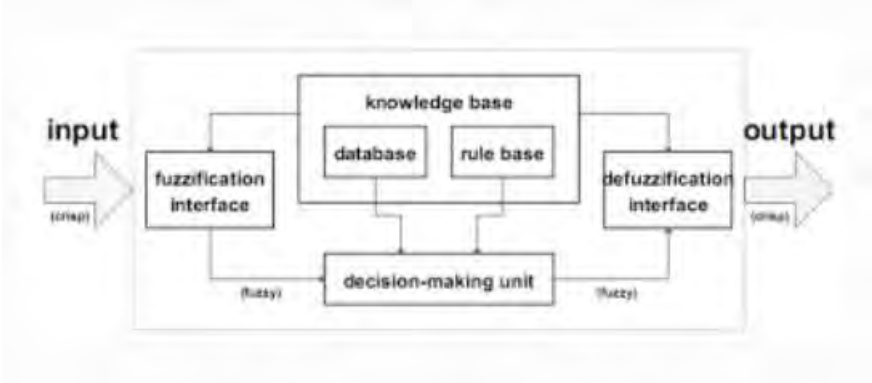

Fig. 2: Fuzzy inference system

The adaptive neuro-fuzzy inference system uses neural network algorithms and fuzzy logic to design nonlinear mapping between input and output space. This system is based on the linguistic power of a fuzzy system with the numerical power of a neural network, in modeling very powerful complex processes [20]. The adaptive neuro-fuzzy inference system is a five-layer network consisting of nodes and a node connecting arc (Fig. 3). The first layer is the input data with a membership degree specified by the user. All modeling operations are carried out in the second to fourth layers. The last layer is the network output which, aims to minimize the difference between the output obtained from the network and the actual output.

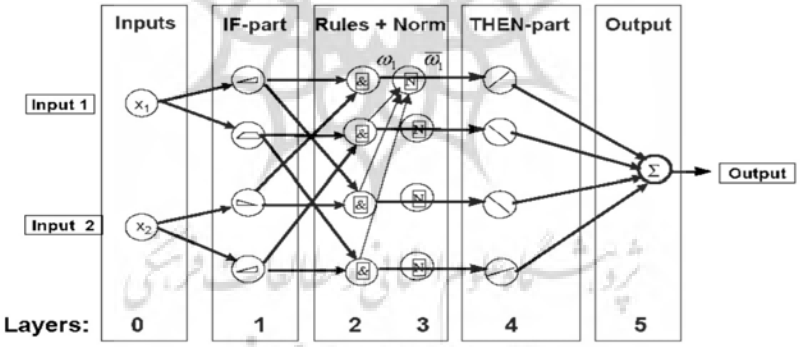

Fig. 3: Adaptive neuro-fuzzy inference system (ANFIS)

In accordance with the input data, the ANFIS degree of membership structure, the rules, and functions of the membership degree are selected. In the training phase, by modifying the membership degree parameters based on the acceptable error rate, the input values become closer to the actual values. There are two methods of grid partitioning and sub-clustering for the use of ANFIS. The main difference between these two methods is in determining the fuzzy membership function. In this study, the grid partitioning method was used. Important parameters for fuzzy neural network modeling to detect financial statement fraud are [21]:

Input variables:

X1 = Current Ratio

X2 = Debt Ratio

X3 = Inventory turnover ratio
X4 = Sales Growth Index
X5 = Total asset turnover ratio
X6 = Capital return ratio
Output variable:
1 = Fraud
0 = Non-Fraud

The fuzzy neural network is an adaptive fuzzy inference system based on artificial neural networks that is widely used to study phenomena with nonlinear equations. Therefore, the combination of fuzzy systems (that are based on logical rules), and artificial neural networks (that can extract knowledge from numerical information), enables the use of existing information in the model building along with the use of human knowledge. To collect information from 10 companies listed in the stock market from 2010 to 2018, their annual statements (80 items) were stored in the database. After clearing and normalizing the data in the range of 1-5, six indices of current ratio, debt ratio, inventory turnover ratio, sales growth index, total asset turnover ratio, and capital return ratio were entered as inputs. They were then classified qualitatively in a discrete range based on a five-point Likert scale of very low, low, normal, high, and very high. After calculating each of the input components such as the current ratio, an appropriate value of 2 is considered for this ratio that is the constant value for the financial statements. For example the amount of 2.5 is obtained for current ratio. As a result, by using 5-point Likert scale, the amount of 4 is assigned for the current ratio of this statement. The output components of fraud detection were also considered zero and one for non-fraud and fraud, respectively. The fuzzy neural network consists of nodes to define membership functions and linear and nonlinear parameters to form fuzzy rules to construct the model in question using data. The fuzzy neural network was developed by using the Sugeno inference algorithm with the grid partitioning method.

4 Implementation of the Fuzzy Neural Network Model

In MATLAB software, after calling data, input data such as current ratio index, debt ratio, inventory turnover ratio, sales growth index, total asset turnover ratio, and capital return ratio, as well as output data related to fraud detection were identified. The fuzzy neural network consists of nodes to define membership functions and linear and nonlinear parameters to form fuzzy rules to construct the model in question using data. The fuzzy neural network was developed by using the Sugeno inference algorithm with Gaussian membership degree by the grid partitioning method.

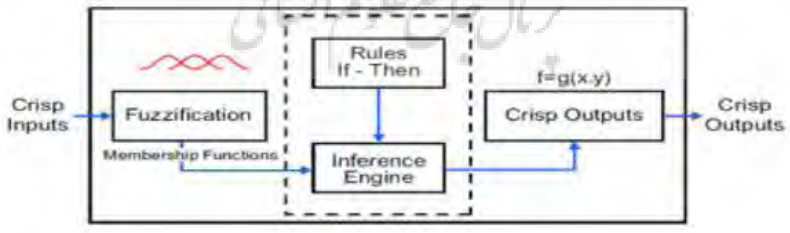

Fig. 4: Sugeno inference system

Sugeno inference algorithm is most commonly used in systems that require mathematical computation, but in the Mamdani inference algorithm, another fuzzy inference algorithm, the logical results are expressed in a relatively simple structure (Fig. 4). The Mamdani algorithm does not perform well

in many functions where output accuracy and flexibility are important, but the Sugeno inference algorithm is more flexible and performs better. Different criteria such as MSE (Mean Squared Error), RMSE (Root Mean Squared Error), and NRMSE are used to estimate the suitability of the prediction. These criteria can be expressed as relations (1) to (3).

$$MSE = \frac{\sum_{i=1}^{n} e_i^2}{n} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} e_i^2}{n}} \quad (2)$$

Normalized Root Mean Squared Error= $RMSE/\ (ymax - ymin)$ (3)

Table 1: Accuracy percent

		Training Set		Test Set	
	METHOD	Non-fraud Data	Fraud Data	Non-fraud Data	Fraud Data
ACCURACY	ANFIS	99%	100%	100%	100%

Table 2: Error rate comparison

	METHOD	NRMSE
	ANFIS	0.0000001
Sorkun & Toraman	Linear Regression	0.4
	ANN	0.51
	SVM	0.53

Table 3: Comparison of accuracy

	Paper/Authors	METHOD	ACCURACY
Comparative	A Comparative Study on Fraud Detection in Financial Statement using Data Mining	Accuracy K-Means	90.01%
		LP	75.50%
		GMDH	65.50%
		Bayesian Belief Networks	85.60%
		PNN	75.60%
		Multi-Level Feed Forward Network	66.16%
		Genetic Programming	55.63%
	Data mining and detection of financial fraud	D3	96.20%
		BBN	94.70%
	A BP Neural Network for Identifying Corporate	BP NN	80.00%
		DA Model	52.00%
		LR Model	72.00%
	Method of this paper	ANSIF	100%

In these relations, n is the number of predictions and e_i is the prediction error, which is obtained from the difference between the predicted values and the actual values. The results of the fraud detection obtained by the fuzzy neural network and the data collected in Fig. 5, illustrate the accurate prediction of model-based fraud. The horizontal axis in Fig. 5 shows a sample of study involving 80 financial statements, and the vertical axis represents the output of the study showing non-fraud (zero) and fraud (one). The blue circles are fraud and non-fraud-based audit detection, and the red stars are the predictions by the ANFIS system. The training data were calculated as zero and 0.00000001 using MSE and RMSE accuracy methods, respectively. The paper presented by Sorkun and Toraman's (2017) is used to compare the error results [22]. In this paper, the estimation accuracy of the model is 0.4, 0.51, and 0.53 by linear regression, artificial neural network, and support vector machine methods, respectively. The comparison of the results shows that the fuzzy neural network model is much better than others. The number obtained by the RMSE method is divided by the difference of the

range of 0 to 1 which results in the same number (0.00000001). The accuracy was also determined using three other papers (Tables 1, 2 and 3). The results of the applied method (ANFIS) and comparison with other studies show good accuracy of the prediction model of this study.

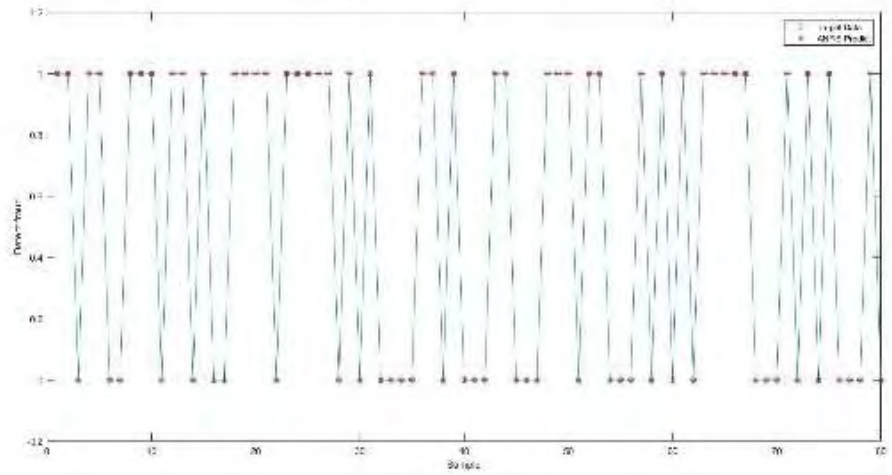

Fig. 5: Fraud detection by the fuzzy neural network

5 Conclusion

Several studies have shown that fuzzy neural networks have not been investigated for fraud detection. The database was compiled annually in 80 rows and 560 records after clearing and normalizing qualitatively to check input data such as current ratio, debt ratio, inventory turnover ratio, sales growth index, total asset turnover ratio, and capital return ratio as input and detection of financial fraud as output. The fuzzy neural network model with 161 nodes, 448 linear parameters, 36 nonlinear parameters, and 64 fuzzy laws with two methods of accuracy approximation of mean squared error (MSE) and root mean squared error (RMSE) has been set to zero and 0.0000001 respectively. The obtained fuzzy neural network is very suitable and can be used for prediction due to the error rate and accuracy of model estimation and comparison with other studies. Overall, the prediction accuracy of the ANFIS is very high and can be considered as the best tool for predicting financial statement fraud.

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