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Using neural network ensembles for bankruptcy prediction and credit scoring

Chih-Fong Tsai *, Jhen-Wei Wu

Department of Accounting and Information Technology, National Chung Cheng University, Taiwan

Abstract

Bankruptcy prediction and credit scoring have long been regarded as critical topics and have been studied extensively in the accounting and finance literature. Artificial intelligence and machine learning techniques have been used to solve these financial decision-making problems. The multilayer perceptron (MLP) network trained by the back-propagation learning algorithm is the mostly used technique for financial decision-making problems. In addition, it is usually superior to other traditional statistical models. Recent studies suggest combining multiple classifiers (or classifier ensembles) should be better than single classifiers. However, the performance of multiple classifiers in bankruptcy prediction and credit scoring is not fully understood. In this paper, we investigate the performance of a single classifier as the baseline classifier to compare with multiple classifiers and diversified multiple classifiers by using neural networks based on three datasets. By comparing with the single classifier as the benchmark in terms of average prediction accuracy, the multiple classifiers only perform better in one of the three datasets. The diversified multiple classifiers trained by not only different classifier parameters but also different sets of training data perform worse in all datasets. However, for the Type I and Type II errors, there is no exact winner. We suggest that it is better to consider these three classifier architectures to make the optimal financial decision.

Keywords: Bankruptcy prediction; Credit scoring; Neural networks; Classifier ensembles

1. Introduction

To predict business failure accurately is a very important issue in financial decision-making. Wrong decision-making in financial institutions can cause important consequences, e.g. financial crises or distress. Two well-known issues in financial decision-making are bankruptcy prediction and credit scoring.

Bankruptcy prediction and credit scoring have long been regarded as critical topics and have been studied extensively in the accounting and finance literature. The main impacts of such research are in lending decisions and profitability of financial institutions. Before extending a loan, banks need to predict the possibility of failure of the potential counterparty. Thus, predicting bankruptcy timely and correctly has become great importance for financial institutions (Atiya, 2001; Zhang, Hu, Patuwo, & Indro, 1999).

With the rapid growth in credit industry and the management of large loan portfolios, credit scoring models have been extensively used for the credit admission evaluation. The credit scoring models are developed to classify loan customers as either a good credit group (accepted) or a bad credit group (rejected) with their related characteristics such as age, income and martial status or based on the data of the previous accepted and rejected applicants (Chen & Huang, 2003). The benefits of using credit scoring include reducing the cost of credit analysis, enabling faster decision, insuring credit collections, and diminishing possible risk (West, 2000). A slight improvement in credit scoring accuracy might reduce large credit risk and translate into significant future saving.

Financial decision-making such as bankruptcy prediction and credit scoring described above, can be regarded as the binary classification problem of classifying an observation

* Corresponding author. Tel.: + 88 652720411x34519; fax: +88 652721197.
E-mail address: actcft@ccu.edu.tw (C.-F. Tsai).

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into one of the two pre-defined groups (in the bankruptcy prediction case, bankruptcy or non-bankruptcy). Artificial intelligence and machine learning techniques (e.g. artificial neural networks (ANN), decision trees (DT), support vector machines (SVM), etc.) have been used to solve the above financial decision-making problems (e.g. Atiya, 2001; Huang, Chen, Hsu, Chen, & Wu, 2004; Lee, Chiu, Chou, & Lu, 2006).

According to previous studies, they show that machine learning techniques are superior to that of traditional (statistical) methods in dealing with bankruptcy prediction and credit scoring problems, especially in nonlinear pattern classification (Huang et al., 2004; Ong, Huang, & Tzeng, 2005; Vellido, Lisboa, & Vaughan, 1999; Wong & Selvi, 1998). In particular, the neural network model trained by the back-propagation learning algorithm is the most popular tool used for financial decision-making problems, whose prediction accuracy outperforms than other models, such as logistic regression (LR), linear discriminant analysis (LDA), multiple discriminant analysis (MDA), k-nearest neighbor (k-NN), decision trees, etc. This indicates that choosing learning model/classifier is one major factor affecting the classification or prediction result. In this paper, we employ the multilayer perceptron neural network trained by the back-propagation learning algorithm as the baseline classifier to compare with multiple neural network classifiers.

Much related work focuses on identifying the single best model for a given financial decision-making problems. This reliance on a single model may be misguided. In West, Dellana, and Qian (2005) "multiple experts" (i.e. ensembles) of predictors have demonstrated the potential to reduce the generalization error of a single model from 5% to 70%. In order words, "multiple classifiers" may provide more accurate prediction results than "single classifiers". However, the performance of using multiple classifiers in the binary classification financial decision-making problems is not fully understood. Therefore, there are two research questions as the aim of this paper.

- Do multiple neural network classifiers outperform the single best neural network classifier in terms of predication accuracy based on a number of datasets?
- By considering the Type I and Type II errors, what kind of neural network classifiers provide the lowest prediction errors?

The organization of this paper is as follows. Section 2 describes the concept of pattern classification and application of multiple classifiers, with a particular attention given to artificial neural networks. Section 3 compares related work in bankruptcy prediction and credit scoring by using machine learning techniques. In Section 4, the experiments are based on comparing the performance of single and multiple classifiers in terms of average prediction accuracy and the type I and type II errors. Finally, the conclusion is made in Section 5.

2. Artificial neural networks and multiple classifiers

2.1. Pattern classification

Pattern classification considers assigning a label to an input. In general, pattern classification is the problem to classify given patterns into several classes. After finding a set of classes, the input represented by a number of features is allocated to the correct class. The general model first determines the class, and then observations are obtained regarding the class. Finally, the model attempts to assign the correct class to the input based on the observations. When defining classes, one can state explicit rules. However, it is better to define through training examples.

There are two approaches regarding how pattern classification is done. One is "decision-theoretic approach." In this approach, the pattern is represented as a feature vector in a feature space and then a decision algorithm is used to decide which class the pattern belongs to. Another one is "structural approach." In this approach, the pattern is represented by its structure, e.g. a graph connecting the primary elements, etc. Subsequently, it uses parsing (grammatical) or graph matching to perform pattern classification (Witten & Frank, 2000).

2.2. Artificial neural networks

A neural network (or an artificial neural network) (Haykin, 1999) is an information processing paradigm that is inspired by the way of biological nervous systems, such as the brain to process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurones) working in unison to solve specific problems. Neural networks, like people, learn by examples. That is, neural networks learn by experience, generalize from previous experiences to new ones, and can make decisions.

The most common type of neural networks consists of three layers of units: input layers, hidden layers, and output layers. It is called multilayer perceptron (MLP). A layer of "input" units is connected to a layer of "hidden" units, which is connected to a layer of "output" units. The activity of the input layers represents the raw information that is fed into the network. The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units. The behavior of the output units depends on the activity of the hidden units and the weights between the hidden and output units. Fig. 1 shows an example of three-layer neural network including input, output, and one hidden layers.

In multilayer networks, the predicted outputs for each training example are calculated, and then it figures out the difference between each predicted output and the corresponding target output. The error is then adjusted so that the error rate will be reduced next time when the training example is presented to the network. Thus, the algorithm