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Fuzzy Support Vector Machine for bankruptcy prediction

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ABSTRACT

Bankruptcy prediction has been a topic of active research for business and corporate organizations since past few decades. The problem has been tackled using various models viz., Statistical, Market Based and Computational Intelligence in the past. Among Computational Intelligence models, Artificial Neural Network has become dominant modeling paradigm. In this Paper, we use a novel Soft Computing tool viz., Fuzzy Support Vector Machine (FSVM) to solve bankruptcy prediction problem. Support Vector Machine is a powerful statistical classification technique based on the idea of Structural Risk Minimization. Fuzzy Sets are capable of handling uncertainty and impreciseness in corporate data. Thus, using the advantage of Machine Learning and Fuzzy Sets prediction accuracy of whole model is enhanced. FSVM is implemented for analyzing predictors as financial ratios. A method of adapting it to default probability estimation is proposed. The test dataset comprises of 50 largest bankrupt organizations with capitalization of no less than $1 billion that filed for protection against creditors under Chapter 11 of United States Bankruptcy Code in 2001–2002 after stock marked crash of 2000. Experimental results on FSVM illustrate that it is better capable of extracting useful information from corporate data. This is followed by a comparative study of FSVM with other approaches. FSVM is effective in finding optimal feature subset and parameters. This is evident from the results thus improving prediction of bankruptcy. The choice of feature subset has positive influence on appropriate kernel parameters and vice versa which demonstrate its appreciable generalization performance than traditional bankruptcy prediction methods. Choosing appropriate value of parameter plays an important role on the performance of FSVM model. The effect of variability in prediction performance of FSVM with respect to various values of different parameters of SVM is also investigated. Finally, a comparative study of clustering power of FSVM is made with PNN on ripley and bankruptcy datasets. The results show that FSVM has superior clustering power than PNN.

1. Introduction

Bankruptcy prediction [5,51] is an important and serious topic for business and corporate organizations. Prediction of corporate bankruptcy is a phenomenon of increasing interest to investors or creditors, borrowing organizations and governments alike. Timely identification of organizations' impending failure is desirable. Bankruptcy is the condition in which an organization cannot meet its debt obligations and petitions federal district court for either reorganization of its debts or liquidation of its assets. In action, the property of debtor is taken over by receiver or trustee in bankruptcy for benefit of creditors. An effective prediction in time is valued priceless for business in order to evaluate risks or prevent bankruptcy [4,5,20]. A fair amount of research has therefore focused on bankruptcy prediction [1,2,6,7,9,10,13–16,18,23,25,30,33,35–37,40–43,45,50,52,53,55,56,58,59,61,63,64,67,69,70,74,81,83].

Signs of potential financial distress are evident long before bankruptcy occurs [5,22]. Financial distress begins when an organization is unable to meet its scheduled payments or when projection of future cash flows points to an inability to do so in near future. The causes leading to business failure and subsequent bankruptcy [22] can be divided into economic, financial, neglect, fraud, disaster and others. Economic factors include industry weakness and poor location. Financial factors include excessive debt and insufficient capital. Research shows that financial difficulties are the result of managerial error and misjudgment. When errors and misjudgments proliferate, it could be a sign of managerial neglect. Corporate fraud became a public concern during late nineties. However, no models are yet available that could detect and flag corporate fraud. Disaster is sometimes the cause of corporate failure. It includes human error and malice.

Bankruptcy filing is not exclusive to any specific economy. Globalization can feed waves of economic distress across societies and national economies after original economy witnesses its deleterious impact. Countries like Japan, Belgium, Thailand, Greece, Hungary etc. are developing their own bankruptcy pre-

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diction models to deter disastrous consequences of ultimate financial distress. Predicting corporate failure using past financial data is a traditional and modern topic of financial business [80,82]. The solution to this problem is discriminant function from variable space in which observations are defined into a binary set. Various researches have demonstrated that Artificial Intelligence (AI) techniques such as Artificial Neural Networks (ANN) [7,8,13,38,39,49,52,53,55,62,66,67,76] can serve as a useful tool for bankruptcy prediction. In early stage of applying ANN to bankruptcy prediction, Back Propagation Neural Networks (BPNN) was used and their prediction results were compared and integrated with other results [38,63]. During past few decades ANN has become a dominant modeling paradigm of bankruptcy prediction though non-ANN methods are still used. Research efforts have been directed to integration of ANN models with other Soft Computing (SC) tools such as Fuzzy Sets (FS) [73], Rough Sets (RS) [81] and Genetic Algorithms (GA) [67,80] for better performance and improvement of predicted results.

Since the work of Beaver in 1966 [12] and Altman in 1968 [3], bankruptcy prediction has been studied actively by academics and practitioners. This field of risk management continues to be very active, much due to the continuous development of new financial derivatives. For example, pricing of credit derivatives rely on good estimates of counterparty risk. The literature on bankruptcy prediction is extensive. Many models have been proposed and tested empirically, often with contradictory conclusions. There are basically three kinds of models that are commonly addressed in literature. First group comprises of Statistical Models, for example discriminant analysis [21], correlation and regression analysis, logit and probit models [32,77] etc. Linear discriminant analysis models have been widely used. Altman's popular z-score [4] is for example based on linear discriminant analysis. Generalized linear or multiple logistic regression models [32] have also been popular. Ohlson's o-score is based on generalized linear models with logit link function is also referred to as logit analysis. The second group belongs to Market Based Models, for example Merton or Black-Scholes Merton (BSM) Models [75] and Moody's KMV Public Firm Model [19,27]. The market models are based on value of firm set by the market. Stock prices are commonly used as proxies for value. Market based models require that firms are registered on stock exchange and this is quite often not the case. The third group encompasses different Computational Intelligence [42] techniques such as decision trees, ANN [38], Support Vector Machines (SVM) [36,63] etc. Most researchers use one of techniques to compare prediction performance with other techniques for specific data set [5,17,36–39,43,63,72]. However, there is no single conclusion that one technique is consistently better than another for general bankruptcy prediction.

Factors which can contribute to understanding of corporate bankruptcy can be found both in the field of Economics and Business Management. However, several attempts to specify model of bankruptcy prediction based on causal specifications of underlying economic determinants has not fully succeeded. The difficulties of merging theoretical and empirical fields may arise from diversity of phenomenon. Organizations are heterogeneous and available information is limited. Furthermore, the event of bankruptcy is twofold as decision of whether or not to continue operations is not directly connected to particular outcome of bankruptcy. In search of explanatory factors we need not only to identify factors that influence on insufficiency of organization's performance but organizations that fail. These organizations need explanation why particular outcome of bankruptcy is observed and not a timely liquidation, merger or restructuring of debt.

SVM has been studied as bankruptcy prediction tool quite often in past [36,38,42,48,55,56,63]. It is a classification method based on Statistical Learning (SL) theory. It has already been successfully applied to optical character recognition, medical diagnostics and text classification. Two applications where SVM outperformed other methods are electric load prediction [26] and optical character recognition [71]. SVM are most widely used nonparametric technique in ANN and are deemed to be most accurate. SVM classification exercise finds hyperplane in possible space for maximizing the distance from hyperplane to data points. This is equivalent to solving a quadratic optimization problem. The solution of strictly convex problems for SVM is unique and global. SVM implements Structural Risk Minimization (SRM) principle that has high generalization performance. As complexity increases by number of support vectors, SVM is constructed through trading off decreasing number of training errors and increasing the risk of over fitting data. However, data dependent SRM for SVM does not rigorously support the argument that good generalization performance of SVM is attributable to SRM [71]. Since SVM captures geometric characteristics of feature space without deriving weights of networks from the training data, it is capable of extracting optimal solution with small training set size. They have flexible structure and produce better classification results than parametric methods. SVM have attractive properties and give single solution characterized by global minimum of optimized functional and not multiple solutions associated with local minima. They do not rely on heuristics and thus are an arbitrary choice to model various problems.

The major prime face of this work is to apply and investigate the effectiveness of SVM with fuzzy membership functions embedded in it leading to the development of Fuzzy Support Vector Machine (FSVM) to corporate bankruptcy analysis. FSVM is implemented for analyzing predictors as financial ratios. A method of adapting it to default probability estimation is proposed. This work shows that FSVM are capable of extracting useful information from financial data as compared to other approaches, although extensive data sets are required in order to fully utilize their classification power. FSVM is effective in finding optimal feature subset and parameters thus improving prediction of bankruptcy. Further, the choice of feature subset has positive influence on appropriate kernel parameters and vice versa which demonstrates its appreciable generalization performance than traditional bankruptcy prediction methods. While there are several arguments that support the observed high accuracy of SVM by choosing appropriate value for parameters, this plays an important role on the performance of the proposed FSVM model. We also investigate the effect of variability in prediction performance of FSVM with respect to various values of parameters C and δ^2. Thus, this paradigm inherits advantages of Machine Learning and Fuzzy Sets such that the prediction accuracy of whole model is enhanced. A comparative study of clustering power of FSVM is also made with Probabilistic Neural Network (PNN) which shows that former has superior clustering power.

The organization of the Paper is as follows: In Section 2, bankruptcy analysis methodology is given alongwith a survey of practically applied methods. In next section, need for risk classification is discussed. In Sections 4 and 5, concepts of SVM and FSVM are given. A brief description of data used for simulation is given in Section 6. In Section 7, experimental results and discussions are presented. A comparative study of performance of FSVM with GA-SVM is highlighted in Section 8. This is followed by a comparison the clustering power of FSVM with PNN. Finally, in Section 10 conclusions are given.

2. Bankruptcy analysis methodology

The early works in bankruptcy analysis were published by late 1960s [3] and mid 1970s [21,22]. Demand from financia1 institutions for investment risk estimation stimulated subsequent research. However, despite substantial interest, the accuracy of cor-