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A Survey on Machine Learning and Statistical Methods for Bankruptcy Prediction

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Abstract— To validate the management or organization's creditworthiness, bankruptcy prediction model (BPM) is significantly important for financial firms. The socio-economic effects can be devastated if there exist a lack in predicting bankruptcy precisely. To anticipate this, it is important to provide financial decision makers with bankruptcy prediction in a efficient manner. To deal with this bankruptcy prediction problems, this paper projects a inclusive review depending on different machine learning and statistical methods. The methods of machine learning includes decision trees, artificial neural networks (ANN) and support vector machines (SVM) whereas the statistical methods such as logistic regression (LR), multivariate discriminant analysis (MDA) and linear discriminant analysis (LDA) are used. To manage huge data sets without degrading performance by means of prediction, conventional statistical methods were employed. For small data sets, the machine learning methods offers better accuracy in terms of predictions when compared with the conventional statistical methods. Depending on the respective methods advantages and drawbacks, this paper examines a comparative study of different methods. To enhance the accuracy for massive data sets, particle swarm optimization (PSO) and genetic algorithm (GA) are the optimization methods that were combined for bankruptcy prediction.

Keywords— *Bankruptcy, ANN; SVM; Machine learning*

I. INTRODUCTION

In financial domain, prediction of bankruptcy is on among the significant problem up streamed by decision makers[1]. It leads to failure that affects users, economics, organization and stockholders etc., The major aim to predict bankruptcy is to search whether a organization or financial institution will bankrupt or not [2]. The financial concern or bankruptcy is a point while a financial organization validates its own responsibilities in finance. The technological growth aids the data procuring in a critical situation of a firm in different way like professional agencies[3] and mass media.

Economic, fraud, financial and disaster are the causes for loss or bankruptcy in business. The factor comprise of industry weakness, worst location or financial impacts that contains huge liabilities.

In management and financial issues [5], accurate bankruptcy prediction is significant issue. non-bankrupt [6] and bankrupt are the two classification that are involved in bankruptcy prediction which is a issue of binary classification. property elimination, repayment, secured liabilities etc., are various bankruptcy elements. Hence, there should a consequent improvement in predicting bankruptcy and financial failure.

Prediction method selection is the initial difficulty in predicting bankruptcy.Machine learning and Statistical method are the two extensive classification that are employed [8] [9]. Logistic regression (LR), multivariate discriminant analysis (MDA) and linear discriminant analysis (LDA), etc., are the statistical methods[10]. Decision trees, Artificial neural networks (ANN) Bayesian network and Support vector machines (SVM) are the machine learning methods [11] [12]. To enhance additionally the accuracy for massive data sets, particle swarm optimization (PSO) and genetic algorithm (GA) [13] are the optimization methods that were combined[14].

Based on the respective methods advantages and drawbacks, this research examines a comparative study of different method in organization and financial domain. Section II is a literature survey that demonstrates different machine learning and statistical methods that had been projected by different researchers. Section III discusses the comparison of different method along with its drawbacks and advantages.

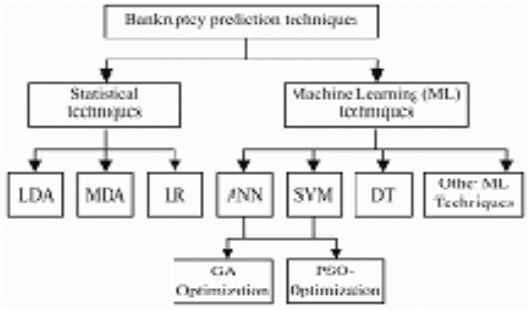

Fig. 1. Classification of bankruptcy prediction models

II. REVIEW OF BANKRUPTCY PREDICTION MODELS

Through different researchers, there are many methods projected that were employed to bankruptcy prediction. Various kinds of bankruptcy prediction method demonstrated in fig. 1.

A. Statistical Techniques

1) Linear discriminant analysis (LDA)

A correlation among traditional statistical methods for distress prediction and classification, to be specific linear discriminant (LDA) with an artificial intelligence algorithm, has been examined [15]. The trial results are a unit of a huge endeavor including distinct structures for mechanical, retail, and development firms. The outcomes exhibit a fair level of accuracy and different beneficial properties among LDA and neural networks (NN). Furthermore, Altman et al. have called attention to the problems of "discovery" NN frameworks, tth comprise of wrong weightings and over fitting in the training stage, the two of which affect prediction accuracy. The two sorts of indicative methodologies show satisfactory classification execution.

2) Multivariate discriminant analysis (MDA)

Multivariate discriminant analysis (MDA) was an achievement in credit risk appraisal that happened while [16] proposed bankruptcy analysis among assembling firms that accomplished relative classification outcomes. The system depends on a minimization in the difference between perceptions in a similar collection and a distance maximization among perceptions in various collections [17]. The system delivers a score and the perception is characterized into a set relying upon the score with respect to a discretionary cut-off rate. The opposite contemplations of MDA need the typically conveyed factors and affectability to anomalies that shaped the LR, in particular the multivariate model for credit risk model.

3) Logistic regression (LR)

Another model has been projected for the prediction of organization fail in the French setting and an enhancement to the previous real-time analysis by including two main new methods [18]. The bankruptcy prediction is accomplished by the use of the considerable number of factors in LR, that are not influenced through multicollinearity. Be that as it may, it has the significant test of assembly issues in most extreme probability calculation. Additionally, this paper demonstrates that the real-time utilization of the fractional least squares technique to organizations fundamental to a few action zones provides great outcomes. The use of this strategy to two examples of solid and failing organizations allowed the authors to get great outcomes and to exhibit a prediction demonstrate more suitable than that procured utilizing the parametric technique. This outcome gives bankers and financial specialists an enlightening portrayal of practices dependent on disappointment pointers. This licenses them to accomplish a near analysis of its distinct models for the financial distress prediction.

For Malaysian firms [19], the incorporated strategy utilized for bankruptcy prediction was projected and verified. The coordinated strategy was fluctuated from traditional analysis about by incorporating the Ohlsonlogit technique, macroeconomic parameters and Springate-Canadian technique. This strategy was enhanced dependent on the finance and macroeconomic developments. The outcomes demonstrated that logistic regression accomplishes better execution and it was utilized to verify the technique. Also, the outcomes show that the limit of the strategy to anticipate effectively is 100% for the two examples.

B. Machine Learning Techniques

1) Artificial neural networks (ANN)

A hybrid discriminant neural system (HDNN) has been projected dependent on self-organizing maps, back-propagation NN, discriminant determination, and to anticipate risk failure [20]. This strategy assumes the manner in that organizations move in space of failure over a time of three years and the restriction of missing data to depict its failure of risk. They used a hybrid model of NN to the Moroccan firms risk failure assuming the data unwavering quality and accessibility. The execution results exhibit that the HDNN gives great accuracy when contrasted with discriminant examination. Moreover, it confirms the theory that a strategy prepared with appropriate factors gives upgraded outcomes than for the most part utilized factors with the missing data. This hybrid strategy is a valuable method for financial specialists and partners to portray the risk profile.

In [21], a productive hybrid methodology utilizing genetic algorithm with artificial neural networks (GA-ANN) algorithm and clustering algorithm has been projected to adjust the extent between the minority and larger part classes. This paper gives a superior suitable data set for both lessening imbalance of data and improving the classification

accuracy. They extricated the reasonably adjusted data set gathered from an ideal circumstance for the ANN method. Also, the methodology extricated the knowledge-based data set prediction and arranged the data by the clustering method when utilizing simultaneous optimization for the ANN method. This methodology was viably connected to the bankruptcy prediction problem utilizing financial data where the extent of little estimated and medium-sized bankruptcy organization is little contrasted with the non-bankruptcy organization in the assembling business.

In the field of corporate bankruptcy [22], a prediction procedure dependent on the application and focal points of data mining has been created. Dependent on various data mining methods, it assesses a data set of 120 enterprises. This NN strategy accomplishes better outcomes in the corporate bankruptcy prediction. Thus, the fitting determination of data mining procedures was utilized to enhance the accuracy of the bankruptcy prediction replica. Financial associations can fundamentally pick up favorable position by utilizing these different prediction models as they grant them to anticipate the state of organizations eventually and settle on choices individually.

In [23], a NN strategy was actualized to the bankruptcy of U.S. Banks, assuming the specific qualities of the present financial problems. They coordinate self-organizing maps and multilayer perceptron to provide a strategy that demonstrates the misery probability as long as 3 years before bankruptcy happened. Utilizing data from the Government Deposit Insurance Corporation somewhere in the range of 2002 and 2012, the exploratory outcomes show that unsuccessful banks are increasingly engaged in land advances. The circumstance is mostly because of hazardous development that outcomes in less parity and intrigue salary. In the wake of illustration the profile of bothered banks, they actualized a strategy to anticipate risk and a technique to dissect bank chance in the short, medium, and long term utilizing insolvencies produced from May 2012 to December 2013 in U.S. banks. The procedures can foresee 96.15% failures in this time and accomplish preferred execution over ordinary systems utilized for bankruptcy prediction.

The demonstrating and execution assessment of the particle swarm optimized fuzzy neural system (PSO-FNN) and neural system strategy has been utilized to tackle the bankruptcy prediction issue [24]. The strategy utilizes a lot of financial data browsed recorded enterprises in the Chinese securities exchange. To think about the two models, the ST (extraordinary treated) organizations speak to the bankrupt companies and non-ST partnerships speak to the non-bankrupt enterprises. The extent of ST organizations in the whole example was structured as 25% dependent on the real proportion. The useful outcomes speak to that the execution of the PSO-FNN method is vastly improved than NN strategies in the bankruptcy prediction field.

Utilizing a back-propagation neural system (BNN) [25], a multi-industry analysis of the bankruptcy of Korean ventures has been displayed. The organization comprise of development, retail, and assembling. It provides an industry related technique to anticipate bankruptcy by picking the fitting factors. The BNN prediction accuracy is better when contrasted with MDA. The outcomes demonatesthat the prediction utilizing an industry test work out superior to anything the prediction utilizing the all out example, which isn't arranged dependent on the business by 6– 12%. The bankruptcy prediction accuracy utilizing BNN is more prominent than that of MDA.

Prediction of Corporate failure utilizing past financial data is an all around archived research strategy. Beforehand, the bankruptcy prediction has been founded on statistical procedures, for example, different probit discriminant analysis and logit. Nonetheless, various methods have appeared artificial intelligence, for example, NNs, is another system that can be utilized for classification problems to that traditional statistical strategies have for some time been utilized. Likewise, various hypothetical and exploratory investigations have affirmed the advantages of NNs in the classification strategy. In any case, the real drawback of NNs is that the client can't understand the guidelines of the NNs method. In [26], GA method were explored and the outcomes demonstrated that GA could be utilized to model bankruptcy prediction. The advantage of this model utilizing GA was the probability to remove guidelines that are straightforward for clients, for example, expert systems. The primer outcomes exhibit that the standard extraction technique utilizing GAs is capable to model bankruptcy prediction.

2)Support vector machines (SVM)

The SVM efficiency for bankruptcy prediction has been examined [27]. Be that as it may, despite the fact that the back-propagation NN functions admirably in the pattern recognition tasks, the method has a couple of disadvantage, consequently it is important to decide a reasonable procedure and best solution. In addition, training set stacking into the system is needed to discover the network loads. The outcomes demonstrate that the SVM classifier performs superior to the BPN for the prediction of corporate bankruptcy. Also, the bankruptcy prediction utilizing SVM demonstrated a superior execution than BPN as far as its accuracy. The researchers have likewise tried the impact of the inconstancy in execution dependent on different estimations of the measurements in SVM.

SVM and hybrid switching particle swarm optimization (SPSO) system has been produced for bankruptcy prediction [28]. The significant target was to utilize the descriptive

power and better stability of the SVM. In common, the built up switching PSO algorithm was material to predict the ideal parameter rates of the outspread premise work piece of the SVM. At that point, the SVM attributes were optimized through the switching PSO method. At long last, the joined procedure was viably utilized to distinguish bankruptcy. The test results demonstrate that the SPSO-SVM performs superior to PSO-SVM, GA-SVM and SVM.

In [29], a few regular statistical systems utilized for financial distress prediction and a couple of eccentric methods, for example, NN, decision tree classification, and transformative estimation procedures, were looked at., The data was gathered from two hundred Taiwan stock trade enterprise recorded organizations for this analysis. The experimentation was directed dependent on the total of 42 proportions comprising of 33 financial, eight non-financial and one incorporated macroeconomic record utilizing principle component analysis (PCA) to separate the proper factors. In this paper, the researchers projected four noteworthy commitments to such an extent that (I) almost 80% less financial proportions have been acquired by the PCA algorithm, that gives high accuracy prediction, (ii) the traditional statistical methods are good on account of expansive data sets without attractive prediction execution and, then again, data mining procedures get better execution with littler data sets, the real time outcomes show that C5.0 and CART provides the ideal prediction accuracy for insolvencies, and (iii) SVMs with transformative estimation aid a decent parity of high accuracy prediction execution. Consequently, the reenactment results exhibit that the PSO joined with SVM (PSO-SVM) strategy can be utilized to perceive potential financial trouble.

3) Decision trees

Decision tree algorithms used for bankruptcy data with the application of accuracy and a number of conditions have been proposed [30]. For bankruptcy data, the decision tree algorithm achieved relatively more accurate when compared to NN and SVM, but there were more condition nodes than required. For financial data, the data mining methods of BPMs, for example, SVM and NNs, are appropriate. Moreover, these algorithms are assumed as black-box methods due to its clarity. Furthermore, decision trees are increasingly exact for clients, notwithstanding, the various number of conditions bring about making immensity. The quantity of conditions achieved from choice tree algorithms is confined somewhat through setting different least aiding levels. Decision tree methods utilized for bankruptcy data with the utilization of accuracy and various conditions have been projected [30]. For bankruptcy data, the decision tree algorithm accomplished progressive accuracy when contrasted with SVM and NN, yet there were more condition nodes than needed.

Machine learning and data mining methods are vital in bankruptcy prediction. The regular method have been produced with different numerous classifiers that outperform a few distinct classifiers. There are a few problems that influence the performance when building the classifiers. In [31], the strategy connected different classifier techniques, for example, multilayer perceptron (MLP), SVM, decision trees (DT) and neural networks to bankruptcy prediction. The trial outcomes show that the DT outfits made out of 80– 100 classifiers utilizing the boosting technique performed better while contrasted with alternate classifiers.

C. Other machine learning techniques

A GA based two-phase classification strategy has been created that allows both picking the noteworthy factors and adjusting the model itself to an application [32]. The different classifier methods are prepared in the initial step and incorporated into the casting a ballot outfit in the second phase. The joining of feature selection and random sampling techniques were utilized to guarantee the essential decent variety dimension of the classifiers in the initial step. Genetic algorithms are utilized in the feature selection step and afterward the loads decided in the outfit. The strategy features were checked on a decent arrangement of data, that comprise of 912 perceptions of Russian organizations and 55 attributes of miniaturized scale business condition factors. The outcomes demonstrate that a most noteworthy accuracy of 0.934 was accomplished. In addition, it additionally exhibited the most adjusted precision-recall proportion. It acquires the non-bankrupts and bankrupts (precision = 0.910) and (recall = 0.953) rather precisely when contrasted with the other tried techniques. In this way, the strategy licenses one to upgrade the advantages and reduce the shortcomings characteristic in the standard classifiers, empowering business decision support with higher unwavering quality.

Corporate bankruptcy prediction has turned into an inexorably vital issue for financial foundations because of the progressed and later financial emergency, and European obligation emergency. In corporate bankruptcy prediction, for bankruptcy prediction [33], a statistical and wise strategy has been created. Ongoing looks into prescribe group learning methods have possible relevance. A new and upgraded boosting, FS-boosting, was actualized to perceive corporate bankruptcy. By infusing a feature selection conspires into boosting, FS-boosting, better performance can be achieved. The exploratory outcomes exhibit the viability and attainability of FS-boosting. Additionally, the outcomes uncover that FS-boosting could be utilized as another technique for corporate bankruptcy prediction.

The validation of prediction methods requires both an in-test and out-of-test estimation of its performance. Be that as it may, TOPSIS (technique for order preference by similarity to ideal solution) classifiers limit a structure for performing its

out-of-test assessment. To address this problem, an example of case-based thinking approach was produced in which the k-closest neighbor was prepared on the aftereffects of a TOPSIS classifier [34]. They assessed the system performance dependent on a UK data set for non-bankrupt and bankrupt firms. The experimental outcomes results exhibit its remarkable prediction performance. Besides, the aftereffects of the proposed structure are autonomous to an assortment of usage decisions.

In [35], a probabilistic perspective by utilizing Gaussian processes (GP) was assumed with regards to alternate techniques. Besides, they made a total bankruptcy prediction, looking at it against SVM and LR. In view of certifiable bankruptcy data, a top to bottom analysis was actualized appearing, additionally a probabilistic translation, the GP can proficiently upgrade the bankruptcy prediction performance with high accuracy when contrasted graphical representation with improve the comprehension of the distinctive accomplished performances, viably assembling all the led trials in a specific way. At last, entropy-based assessment was utilized to enhance the vulnerability taking care of properties offered by GP, which is essential for prediction processes under extremely focused and unpredictable business situations.

A kernel extreme learning machine (KELM) attribute tuning plan has been introduced utilizing a swarm intelligence method, in particular gray wolf optimization (GWO) [36]. GWO recreates the social chain of importance and chasing job of gray posers. This technique was received to manufacture a proficient KELM approach for bankruptcy prediction. The inferred GWO-KELM show was unequivocally contrasted and three KELM algorithms, for example, particle swarm optimization based KELM, a genetically algorithm based KELM, lattice look technique based KELM and enhanced extreme learning machine on two constant data sets through 10-crease cross-approval analysis. The experimental results affirm the prevalence of the actualized methodology utilizing the classification accuracy and computational time. Consequently, the GWO-KELM prediction method was affirmed as a hearty early cautioning tool with prevalent performance for bankruptcy prediction.

A practical bankruptcy prediction dependent on a hybrid algorithm and learning vector quantization (LVQ) technique has been proposed [37]. The unbalanced expenses of two kinds of errors were joined into the transformative classification demonstrate utilized for the prediction of bankruptcy. The genetic algorithm is utilized to scan the solution space for an ideal portrayal of the LVQ method. The experiment was directed on practical bankruptcy data and demonstrated that the hybrid method tends to lower whole misclassification cost while contrasted with the Sole-LVQ, that does exclude the expenses and cost-LVQ, that utilizes a nearby pursuit procedure.

III. COMPARISON OF THE VARIOUS TECHNIQUES

To design a bankruptcy prediction model, the prediction method uses non-financial and financial data and examine the method's performance depending on four performance measures involving precision, specificity[29], sensitivity and accuracy. Depending on the false positive (FP), thetrue positive (TP), false negative (FN) and true negative (TN), the measures are computed; hence to estimate the precision, specificity, sensitivity and accuracy. Here, FN and FP demonstrates the incorrect classification outcomes that are obtained and TN and TP demonstrates the classifier achieving perfect classification.

- Accuracy is described as proportion of rightly classified instances and is employed to calculate the classification performance.

  Accuracy=TP+TN/TP+TN+FP+FN
- Precision is described as the sum of positive cases.

  Precision=TP/TP+FP
- Sensitivity is described as the proportion of the sum of true positive instances to the sum positive instances.

  Sensitivity= TP/TP+FN
- Specificity is described as the proportion of the sum of true negative instances to the sum of negative instances.

  Specificity=TN/TN+FP

Different bankruptcy algorithm performance analysis is discussed depending on the attributes like precision, specificity, accuracy and specificity [29]. By means of four performance measures, Machine learning algorithms like SVM and ANN gains enhanced performance. By combining the optimization algorithms like PSO and GA, the researchers

Table 1 Comparative analysis of different methods interms of accuracy and precision

Methods	Accuracy	Precision
LDA	75.47	68.75
LR	79.25	71.87
DT	86.79	78.12
LVQ	87.5	85
ANN	90	94.11
SVM	90	94.11
SVM-GA	92.5	94.44
SVM-PSO	95	94.73

Table 2 Comparative analysis of different methods interms of sensitivity and specificity

Methods	Sensitivity	Specificity
LDA	64.28	88
LR	67.85	92
DT	75	100
LVQ	95.23	89.47
ANN	85.23	84.21
SVM	95.23	84.21
SVM-GA	95.23	89.47
SVM-PSO	95. 23	94.73

enhanced the performance. While comparing with other methods, the decision tree methods gains huge sensitivity of 100%. It is observed from the overall examination, the SVM-PSO prediction algorithm gained a higher precision, specificity and accuracy while comparing with other machine learning and statistical methods. Table I and Table II demonstrates the performance examination charts of bankruptcy prediction model. Comparative analysis is shown in Figs. 2-5 for sensitivity, accuracy, specificity and precision correspondingly.

A comparative analysis of the various bankruptcy prediction models is shown in Table III. This comparison table provides the advantages and research gaps of each technique.

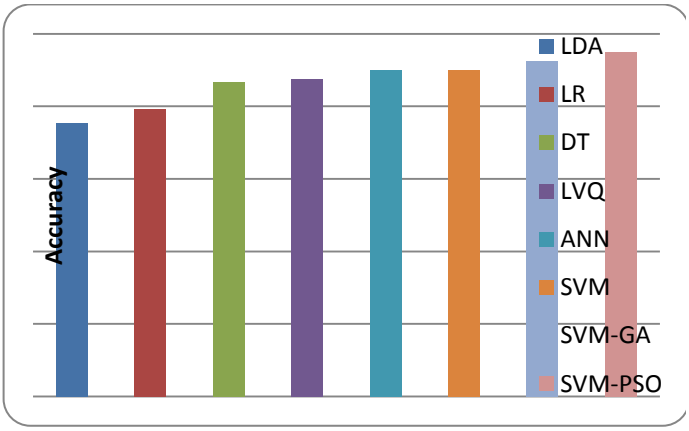

Fig. 2. Results analysis interms of accuracy

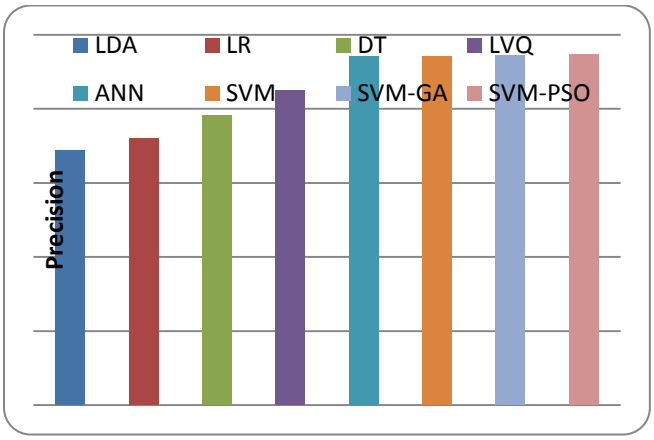

Fig. 3. Results analysis interms of precision

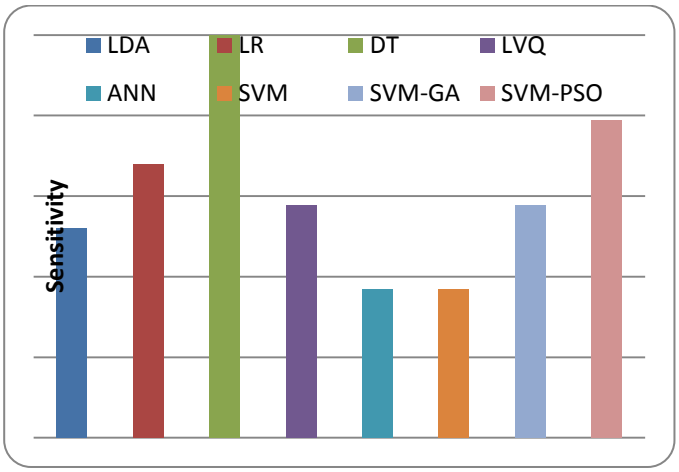

Fig. 4. Results analysis interms of sensitivity

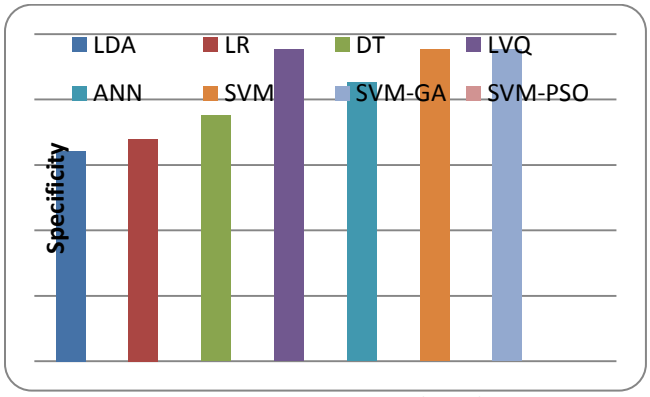

Fig. 5. Results analysis interms of specificity

TABLE III: A COMPARATIVE ANALYSIS OF THE VARIOUS BANKRUPTCY PREDICTION MODELS

Paper Title	Methodology	Outcome	Research Gap
Corporate Distress diagnosis: Comparisons using linear	LDA	Achieved the prediction accuracy of 90%.	More time consumption with moderate complexity.

Discriminant analysis and NNs			
Detecting credit card fraud by modified Fisher Discriminant Analysis	MDA	Better performance when compared to LDA.	More complexity.
Bankruptcy prediction using Partial Least Squares Logistic Regression	LR	More appropriate results are achieved.	Convergence issue in maximum likelihood computation.
Bankruptcy prediction using data mining Techniques	ANN	Obtained good performance with better prediction accuracy.	It requires more training data sets.
A comparative study of Classifier ensembles for Bankruptcy Prediction	DT	Higher accuracy performance when compared to ANN and SVM.	Decision trees without boosting method provide less accuracy.
A hybrid switching PSO algorithm and support vector machines for Bankruptcy Prediction	PSO-SVM	PSO-SVM achieves better performance compared to SVM, GA-SVM.	It is very difficult when the number of data sets is increased.

IV. DISCUSSION

The problem of bankruptcy prediction is reviewed using various Machine Learning and Statistical methods. From many studies existing in the literature, it can be seen that the method's performance is depending on four performance measures. They are listed below:

- **Precision** is sum of positive cases
- **Specificity** is the proportion of the sum of true negative instances to the sum of negative instances
- **Sensitivity is** the proportion of the sum of true positive instances to the sum positive instances
- **Accuracy** is to calculate the classification performance

These measures are used to evaluate each algorithm for financial prediction performance by applying classification methods to the dataset.In addition to that, the various observations are:

- The decision tree methods gains huge sensitivity of 100%
- The SVM-PSO prediction algorithm gained a higher precision, specificity and accuracy while comparing with other methodologies.
- Particle swarm optimization (PSO) and genetic algorithm (GA) are generally more superior to other techniques in case of optimization.

From the above methodologies, LDA had an estimated overall accuracy rate of 75.47% , then the accuracy rate improved to 82.32%, and the error rate sharply dropped to 17.68% indicating that LDA and LR provide stable prediction capability for short-term and long-term.Second, SVM has an estimated overall accuracy rate of 87.5.Hence, the next step for the accuracy enhancement is to implement the classification using Deep Neural Network(DNN) Algorithm, which improve the further performance of predicting bankruptcy. This can be explained by the tendency of the equity markets to be highly predictive, not only of the health of a firm, but also of the health of the economy, which in turn affects the creditworthiness of the firm.

V. CONCLUSION

In this paper, the studies that relate to different bankruptcy prediction methods has been discovered and discussed. machine learning and statistical techniques are used to predict bankruptcy in terms of different method are discussed. Under different measures like sensitivity, accuracy, precision, and specificity, the estimation of these method were done. From this review, SVM-PSO prediction algorithm gains the greater specificity, accuracy and precision when comparing with conventional machine learning and statistical algorithms.

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