**BÁO CÁO CHẤM ĐIỂM TÍN DỤNG CỦA KHÁCH HÀNG**

**TÀI LIỆU THAM KHẢO**

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| **ID** | **CITE** | **ABSTACT** |
| **1** | @article{Gunnarsson2021DeepLF,  title={Deep learning for credit scoring: Do or don't?},  author={Bj{\"o}rn Rafn Gunnarsson and Seppe vanden Broucke and Bart Baesens and Mar{\'i}a {\'O}skarsd{\'o}ttir and Wilfried Lemahieu},  journal={Eur. J. Oper. Res.},  year={2021},  volume={295},  pages={292-305}, | [Deep learning for credit scoring: Do or don't?](https://www.semanticscholar.org/paper/Deep-learning-for-credit-scoring%3A-Do-or-don't-Gunnarsson-Broucke/d756c5bd748444ab2db03a2ebebffe9552266465)  Developing accurate analytical credit scoring models has become a major focus for financial institutions. For this purpose, numerous classification algorithms have been proposed for credit scoring. However, the application of deep learning algorithms for classification has been largely ignored in the credit scoring literature. The main motivation for this research is to consider the appropriateness of deep learning algorithms for credit scoring. To this end two deep learning architectures are constructed, namely a multilayer perceptron network and a deep belief network, and their performance compared to that of two conventional methods and two ensemble methods for credit scoring. The models are then evaluated using a range of credit scoring data sets and performance measures. Furthermore, Bayesian statistical testing procedures are introduced in the context of credit scoring and compared to frequentist non-parametric testing procedures which have traditionally been considered best practice in credit scoring. This comparison will highlight the benefits of Bayesian statistical procedures and secure empirical findings. Two main conclusions emerge from comparing the different classification algorithms for credit scoring. Firstly, the ensemble method, XGBoost, is the best performing method for credit scoring of all the methods considered here. Secondly, deep neural networks do not outperform their shallower counterparts and are considerably more computationally expensive to construct. Therefore, deep learning algorithms do not seem to be appropriate models for credit scoring based on this comparison and XGBoost should be preferred over the other credit scoring methods considered here when classification performance is the main objective of credit scoring activities. |
| **2** | @article{Bueff2022MachineLI,  title={Machine learning interpretability for a stress scenario generation in credit scoring based on counterfactuals},  author={Andreas Bueff and Mateusz Cytrynski and Raffaella Calabrese and Matthew Jones and John Roberts and Jonathon Moore and Iain Brown},  journal={Expert Syst. Appl.},  year={2022},  volume={202},  pages={117271}, | [Machine learning interpretability for a stress scenario generation in credit scoring based on counterfactuals](https://www.semanticscholar.org/paper/Machine-learning-interpretability-for-a-stress-in-Bueff-Cytrynski/2e6b6c2e96ac7f8e70ca3b305b50726df3bf4d0b)  To boost the application of machine learning (ML) techniques for credit scoring models, the blackbox problem should be addressed. The primary aim of this paper is to propose a measure based on counterfactuals to evaluate the interpretability of a ML credit scoring technique. Counterfactuals assist with understanding the model with regard to the classification decision boundaries and evaluate model robustness. The second contribution is the development of a data perturbation technique to generate a stress scenario. We apply these two proposals to a dataset on UK unsecured personal loans to compare logistic regression and stochastic gradient boosting (SBG). We show that training a blackbox model (SGB) as conditioned on our data perturbation technique can provide insight into model performance under stressed scenarios. The empirical results show that our interpretability measure is able to capture the classification decision boundary, unlike AUC and the classification accuracy widely used in the banking sector. |
| **3** | @article{Du2022ExplorationOF,  title={Exploration of Financial Market Credit Scoring and Risk Management and Prediction Using Deep Learning and Bionic Algorithm},  author={Peng Du and Hong Shu},  journal={J. Glob. Inf. Manag.},  year={2022},  volume={30},  pages={1-29}, | [Exploration of Financial Market Credit Scoring and Risk Management and Prediction Using Deep Learning and Bionic Algorithm](https://www.semanticscholar.org/paper/Exploration-of-Financial-Market-Credit-Scoring-and-Du-Shu/daaf0525bc43a807de0bf4968948b5fd36c19818)  The purpose is to effectively manage the financial market, comprehensive assess personal credit, reduce the risk of financial enterprises. Given the systemic risk problem caused by the lack of credit scoring in the existing financial market, a credit scoring model is put forward based on the deep learning network. The proposed model uses RNN (Recurrent Neural Network) and BRNN (Bidirectional Recurrent Neural Network) to avoid the limitations of shallow models. Afterward, to optimize path analysis, bionic optimization algorithms are introduced, and an integrated deep learning model is proposed. Finally, a financial credit risk management system using the integrated deep learning model is proposed. The probability of default or overdue customers is predicted through verification on three real credit data sets, thus realizing the credit risk management for credit customers. |
| **4** | @article{HussinAdamKhatir2022MachineLM,  title={Machine Learning Models and Data-Balancing Techniques for Credit Scoring: What Is the Best Combination?},  author={Ahmed Almustfa Hussin Adam Khatir and Marco Bee},  journal={Risks},  year={2022}, | [Machine Learning Models and Data-Balancing Techniques for Credit Scoring: What Is the Best Combination?](https://www.semanticscholar.org/paper/Machine-Learning-Models-and-Data-Balancing-for-What-Khatir-Bee/de7cf9197d8af4974e4b80b9ef08e287979ed19d)  Forecasting the creditworthiness of customers is a central issue of banking activity. This task requires the analysis of large datasets with many variables, for which machine learning algorithms and feature selection techniques are a crucial tool. Moreover, the percentages of “good” and “bad” customers are typically imbalanced such that over- and undersampling techniques should be employed. In the literature, most investigations tackle these three issues individually. Since there is little evidence about their joint performance, in this paper, we try to fill this gap. We use five machine learning classifiers, and each of them is combined with different feature selection techniques and various data-balancing approaches. According to the empirical analysis of a retail credit bank dataset, we find that the best combination is given by random forests, random forest recursive feature elimination and random oversampling. |
| **5** | @article{Schmitt2022DeepLV,  title={Deep Learning vs. Gradient Boosting: Benchmarking state-of-the-art machine learning algorithms for credit scoring},  author={Marc Schmitt},  journal={ArXiv},  year={2022},  volume={abs/2205.10535}, | [Deep Learning vs. Gradient Boosting: Benchmarking state-of-the-art machine learning algorithms for credit scoring](https://www.semanticscholar.org/paper/Deep-Learning-vs.-Gradient-Boosting%3A-Benchmarking-Schmitt/f302b3027c6ccb7e9e79da09ddbd52da936d011c)  Artificial intelligence (AI) and machine learning (ML) have become vital to remain competitive for financial services companies around the globe. The two models currently competing for the pole position in credit risk management are deep learning (DL) and gradient boosting machines (GBM). This paper benchmarked those two algorithms in the context of credit scoring using three distinct datasets with different features to account for the reality that model choice/power is often dependent on the underlying characteristics of the dataset. The experiment has shown that GBM tends to be more powerful than DL and has also the advantage of speed due to lower computational requirements. This makes GBM the winner and choice for credit scoring. However, it was also shown that the outperformance of GBM is not always guaranteed and ultimately the concrete problem scenario or dataset will determine the final model choice. Overall, based on this study both algorithms can be considered state-of-the-art for binary classification tasks on structured datasets, while GBM should be the go-to solution for most problem scenarios due to easier use, significantly faster training time, and superior accuracy. |
| **6** | @article{Hayashi2022EmergingTI,  title={Emerging Trends in Deep Learning for Credit Scoring: A Review},  author={Yoichi Hayashi},  journal={Electronics},  year={2022}, | [Emerging Trends in Deep Learning for Credit Scoring: A Review](https://www.semanticscholar.org/paper/Emerging-Trends-in-Deep-Learning-for-Credit-A-Hayashi/525154a48bf16d3286602807b01d595127f70360)  This systematic review aims to provide deep insights on emerging trends in, and the potential of, advanced deep learning techniques, such as machine learning algorithms being partially replaced by deep learning (DL) algorithms for credit scoring owing to the higher accuracy of the latter. This review also seeks to explain the reasons that deep belief networks (DBNs) can achieve higher accuracy than shallower networks, discusses the potential classification capabilities of DL-based classifiers, and bridges DL and explainable credit scoring. The theoretical characteristics of DBNs are also presented along with the reasons for their higher accuracy compared to that of shallower networks. Studies published between 2019 and 2022 were analysed to review and compare the most recent DL techniques that have been found to achieve higher accuracies than ensemble classifiers, their hybrids, rule extraction methods, and rule-based classifiers. The models reviewed in this study were evaluated and compared according to their accuracy and area under the receiver operating characteristic curve for the Australian, German (categorical), German (numerical), Japanese, and Taiwanese datasets, which are commonly used in the credit scoring community. This review paper also explains how tabular datasets are converted into images for the application of a two-dimensional convolutional neural network (CNN) and how “black box” models using local and global rule extraction and rule-based methods are applied in credit scoring. Finally, a new insight on the design of DL-based classifiers for credit scoring datasets is provided, along with a discussion on promising future research directions. |
| **7** | @article{Lenka2022EmpiricalAO,  title={Empirical Analysis of Ensemble Learning for Imbalanced Credit Scoring Datasets: A Systematic Review},  author={Sudhansu R. Lenka and Sukant Kishoro Bisoy and Rojalina Priyadarshini and Mangal Sain},  journal={Wireless Communications and Mobile Computing},  year={2022}, | [Empirical Analysis of Ensemble Learning for Imbalanced Credit Scoring Datasets: A Systematic Review](https://www.semanticscholar.org/paper/Empirical-Analysis-of-Ensemble-Learning-for-Credit-Lenka-Bisoy/6ffc5fe55a0fdc6349fe45c44f4afb1612feb5d1)  Credit scoring analysis has gained tremendous importance for researchers and the financial industries around the globe. It helps the financial industries to grant credits or loans to each deserving applicant with zero or minimal risks. However, developing an accurate and effective credit scoring model is a challenging task due to class imbalance and the presence of some irrelevant features. Recent researches show that ensemble learning has achieved supremacy in this field. In this paper, we performed an extensive comparative analysis of ensemble algorithms to bring further improvements in the algorithm oversampling, and feature selection (FS) techniques are implemented. The relevant features are identified by utilizing three FS techniques, such as information gain (IG), principal component analysis (PCA), and genetic algorithm (GA). Additionally, a comparative performance analysis is performed using 5 base and 14 ensemble models on three credit scoring datasets. The experimental results exhibit that the GA-based FS technique and CatBoost algorithm perform significantly better than other models in terms of five metrics, i.e., accuracy (ACC), area under the curve (AUC), F1-score, Brier score (BS), and Kolmogorov-Smirnov (KS). |
| **8** | @article{Jammalamadaka2022ResponsibleAI,  title={Responsible AI in automated credit scoring systems},  author={Krishna Ravali Jammalamadaka and Srikanth Itapu},  journal={AI and Ethics},  year={2022},  pages={1-11}, | [Responsible AI in automated credit scoring systems](https://www.semanticscholar.org/paper/Responsible-AI-in-automated-credit-scoring-systems-Jammalamadaka-Itapu/be8c380ca4cf65f53d996050c57ce38c427ac77b)  In the last few years, Artificial Intelligence (AI) has achieved a notable momentum that, may deliver the expectations over many application sectors across the field. For this to occur, expert systems and rule-based models need to overcome the limitation of fairness and interpretability. Paradigms underlying this problem fall within the so-called explainable AI (XAI) field. This report presents the work on German credit card dataset to overcome the challenges of fairness, bias and in return, deem the machine learning models giving a responsible expectation. This is defined as responsible AI in practice. Since the dataset we dealt with, is to classify credit score of a user as good or bad, using fair ML modelling approach, the key metric of interest is the F1-score to reduce share of misclassifications. It is observed that hyper parameter tuned XGBoost model (GC2) gives optimal performance in terms of both F1-score, accuracy and fairness for the case of both gender and age as protected variable through Disparate Impact Remover, a pre-processing bias mitigation technique. The same is deployed using both Heroku through Flask API (for age). The Disparate Impact Analysis (DIA) using H2O.AI helped to identify optimum threshold levels at which the fairness metrics are observed at legally acceptable/permissible levels for both age and gender. Overall, fairness, bias responsibility and explainability have been established for the dataset considered. |
| **9** | @article{Zhong2023InternetFC,  title={Internet Financial Credit Scoring Models Based on Deep Forest and Resampling Methods},  author={Yuyue Zhong and Huiling Wang},  journal={IEEE Access},  year={2023},  volume={11},  pages={8689-8700}, | [Internet Financial Credit Scoring Models Based on Deep Forest and Resampling Methods](https://www.semanticscholar.org/paper/Internet-Financial-Credit-Scoring-Models-Based-on-Zhong-Wang/79cd2330c380f102a95673466909e47cc0c29d02)  In recent years, deep learning credit scoring models have become a hot research topic in Internet finance. However, most of the existing studies are based on deep neural network models, whose structure is difficult to design. Moreover, previous research seldom considers the impact of class imbalance problems on credit scoring performance. To fill this gap, we propose a new deep learning credit scoring model based on deep forest (DF) and resampling methods. First, we combine DF with five resampling methods including random over-sampling (ROS), random under-sampling (RUS), synthetic minority over-sampling technique (SMOTE), tomek links and SMOTE+ Tomek, respectively, to build responding models. We validate that the RUS-DF model has the best credit scoring performance among the above models. Then, to further evaluate the advantages of the deep ensemble model RUS–DF, we compare it with four models building by combining RUS with multilayer perceptron, convolutional neural network, and long short-term memory and random forests, respectively. All the experiments are conducted on four Internet financial credit scoring datasets. The results show that the RUS-DF model obtains better classification performance and stability than other models and is suitable for solving the credit scoring problem with imbalanced data. |
| **10** | @article{Szepannaek2023HowMD,  title={How much do we see? On the explainability of partial dependence plots for credit risk scoring},  author={Gero Szepannaek and Karsten L{\"u}bke},  journal={Argumenta Oeconomica},  year={2023}, | [How much do we see? On the explainability of partial dependence plots for credit risk scoring](https://www.semanticscholar.org/paper/How-much-do-we-see-On-the-explainability-of-partial-Szepannaek-L%C3%BCbke/ac88c05115f872e73b4dc3a2be4f3c60db9f10a1)  Risk prediction models in credit scoring have to fulfil regulatory requirements, one of which consists in the interpretability of the model. Unfortunately, many popular modern machine learning algorithms result in models that do not satisfy this business need, whereas the research activities in the field of explainable machine learning have strongly increased in recent years. Partial dependence plots denote one of the most popular methods for model-agnostic interpretation of a feature’s effect on the model outcome, but in practice they are usually applied without answering the question of how much can actually be seen in such plots. For this purpose, in this paper a methodology is presented in order to analyse to what extent arbitrary machine learning models are explainable by partial dependence plots. The proposed framework provides both a visualisation, as well as a measure to quantify the explainability of a model on an understandable scale. A corrected version of the German credit data, one of the most popular data sets of this application domain, is used to demonstrate the proposed methodology. |
| **11** | @article{Tyagi2022AnalyzingML,  title={Analyzing Machine Learning Models for Credit Scoring with Explainable AI and Optimizing Investment Decisions},  author={Swati Tyagi},  journal={ArXiv},  year={2022},  volume={abs/2209.09362}, | [Analyzing Machine Learning Models for Credit Scoring with Explainable AI and Optimizing Investment Decisions](https://www.semanticscholar.org/paper/Analyzing-Machine-Learning-Models-for-Credit-with-Tyagi/d8cc1eefda1e64b7d4a45fb4394bf140f676b2ad)  This paper examines two different yet related questions related to explainable AI (XAI) practices. Machine learning (ML) is increasingly important in financial services, such as pre-approval, credit underwriting, investments, and various front-end and back-end activities. Machine Learning can automatically detect non-linearities and interactions in training data, facilitating faster and more accurate credit decisions. However, machine learning models are opaque and hard to explain, which are critical elements needed for establishing a reliable technology. The study compares various machine learning models, including single classifiers (logistic regression, decision trees, LDA, QDA), heterogeneous ensembles (AdaBoost, Random Forest), and sequential neural networks. The results indicate that ensemble classifiers and neural networks outperform. In addition, two advanced post-hoc model agnostic explainability techniques - LIME and SHAP are utilized to assess ML-based credit scoring models using the open-access datasets offered by US-based P2P Lending Platform, Lending Club. For this study, we are also using machine learning algorithms to develop new investment models and explore portfolio strategies that can maximize profitability while minimizing risk. |
| **12** | @inproceedings{Visantavarakul2023AnAO,  title={An application of reinforcement learning to credit scoring based on the logistic Bandit framework},  author={Kantapong Visantavarakul},  year={2023}, | [An application of reinforcement learning to credit scoring based on the logistic Bandit framework](https://www.semanticscholar.org/paper/An-application-of-reinforcement-learning-to-credit-Visantavarakul/16d50bc6e19aef4b4c948263aaf49ba4eeb445b1)  This study applies reinforcement learning to credit scoring by using the logistic bandit framework. The credit scoring and the credit underwriting are modeled into a single sequential decision problem where the credit underwriter takes a sequence of actions over an indefinite number of time steps. The traditional credit scoring approach considers the model construction separately from the underwriting process. This approach is identified as a greedy algorithm in the reinforcement learning literature, which is commonly believed to be inferior to an efficient reinforcement learning approach such as Thompson sampling. This is true under the simple setting, i.e., granting credit to a single borrower per action while the pool of the borrowers is fixed. However, under the more realistic scenario where these two conditions are relaxed, the greedy approach can outperform Thompson sampling since the greedy algorithm does not commit too early to an inferior action as it does in the simple setting. Still, the efficient exploration feature of Thompson sampling is beneficial. When the borrower characteristics are captured by a large number of features, the exploration mechanism enables Thompson sampling to outperform the greedy algorithm. The results from the simulation study permit a deeper understanding of the reinforcement learning approaches towards the logistic bandits, especially in the setting of credit scoring and credit underwriting processes. |
| **13** | @article{Jakka2023ANC,  title={A novel credit scoring system in financial institutions using artificial intelligence technology},  author={Geethamanikanta Jakka and Amrutanshu Panigrahi and Abhilash Pati and Manmath Nath Das and Jyotsnarani Tripathy},  journal={Journal of Autonomous Intelligence},  year={2023}, | [A novel credit scoring system in financial institutions using artificial intelligence technology](https://www.semanticscholar.org/paper/A-novel-credit-scoring-system-in-financial-using-Jakka-Panigrahi/95194d16d0eae2adc079830306a511a99c797be0)  In order to evaluate a person’s or a company’s creditworthiness, financial institutions must use credit scoring. Traditional credit scoring algorithms frequently rely on manual and rule-based methods, which can be tedious and inaccurate. Recent developments in artificial intelligence (AI) technology have opened up possibilities for creating more reliable and effective credit rating systems. The data are pre-processed, including scaling using the 0–1 normalization method and resolving missing values by imputation. Information gain (IG), gain ratio (GR), and chi-square are three feature selection methodologies covered in the study. While GR normalizes IG by dividing it by the total entropy of the feature, IG quantifies the reduction in total entropy by adding a new feature. Based on chi-squared statistics, the most vital traits are determined using chi-square. This research employs different ML models to develop a hybrid model for credit score prediction. The ML algorithms support vector machine (SVM), neural networks (NNs), decision trees (DTs), random forest (RF), and logistic regression (LR) classifiers are employed here for experiments along with IG, GR, and chi-square feature selection methodologies for credit prediction over Australian and German datasets. The study offers an understanding of the decision-making process for informative characteristics and the functionality of machine learning (ML) in credit prediction tasks. The empirical analysis shows that in the case of the German dataset, the DT with GR feature selection and hyperparameter optimization outperforms SVM and NN with an accuracy of 99.78%. For the Australian dataset, SVM with GR feature selection outperforms NN and DT with an accuracy of 99.98%. |
| **14** | @article{Mokheleli2023MachineLA,  title={Machine Learning Approach for Credit Score Predictions},  author={Tsholofelo Mokheleli and Tinofirei Museba},  journal={Journal of Information Systems and Informatics},  year={2023}, | [Machine Learning Approach for Credit Score Predictions](https://www.semanticscholar.org/paper/Machine-Learning-Approach-for-Credit-Score-Mokheleli-Museba/914eed4ccc864679aa5f59e68f447327dd753746)  This paper addresses the problem of managing the significant rise in requests for credit products that banking and financial institutions face. The aim is to propose an adaptive, dynamic heterogeneous ensemble credit model that integrates the XGBoost and Support Vector Machine models to improve the accuracy and reliability of risk assessment credit scoring models. The method employs machine learning techniques to recognise patterns and trends from past data to anticipate future occurrences. The proposed approach is compared with existing credit score models to validate its efficacy using five popular evaluation metrics, Accuracy, ROC AUC, Precision, Recall and F1\_Score. The paper highlights credit scoring models’ challenges, such as class imbalance, verification latency and concept drift. The results show that the proposed approach outperforms the existing models regarding the evaluation metrics, achieving a balance between predictive accuracy and computational cost. The conclusion emphasises the significance of the proposed approach for the banking and financial sector in developing robust and reliable credit scoring models to evaluate the creditworthiness of their clients. |
| **15** | @article{Arram2023CreditCS,  title={Credit card score prediction using machine learning models: A new dataset},  author={Anas Arram and Masri Ayob and Musatafa Abbas Abbood Albadr and Alaa Sulaiman and Dheeb Albashish},  journal={ArXiv},  year={2023},  volume={abs/2310.02956}, | [Credit card score prediction using machine learning models: A new dataset](https://www.semanticscholar.org/paper/Credit-card-score-prediction-using-machine-learning-Arram-Ayob/6d9343d5af5ea0dab0cc99ff76bf422a90262940)  The use of credit cards has recently increased, creating an essential need for credit card assessment methods to minimize potential risks. This study investigates the utilization of machine learning (ML) models for credit card default prediction system. The main goal here is to investigate the best-performing ML model for new proposed credit card scoring dataset. This new dataset includes credit card transaction histories and customer profiles, is proposed and tested using a variety of machine learning algorithms, including logistic regression, decision trees, random forests, multi-layer perceptron (MLP) neural network, XGBoost, and LightGBM. To prepare the data for machine learning models, we perform data pre-processing, feature extraction, feature selection, and data balancing techniques. Experimental results demonstrate that MLP outperforms logistic regression, decision trees, random forests, LightGBM, and XGBoost in terms of predictive performance in true positive rate, achieving an impressive area under the curve (AUC) of 86.7% and an accuracy rate of 91.6%, with a recall rate exceeding 80%. These results indicate the superiority of MLP in predicting the default customers and assessing the potential risks. Furthermore, they help banks and other financial institutions in predicting loan defaults at an earlier stage. |
| **16** | @article{Zhang2023CreditCD,  title={Credit Card Default Prediction based on Machine Learning Techniques},  author={Zixuan Zhang},  journal={BCP Business \& Management},  year={2023}, | [Credit Card Default Prediction based on Machine Learning Techniques](https://www.semanticscholar.org/paper/Credit-Card-Default-Prediction-based-on-Machine-Zhang/18008996a51623b7cdc322ef8166964804cc265b)  In recent years, with the development of society and economy, credit cards have been popularized due to their low interest rate and easy payment. However, with the advent of the epidemic era, the unemployment rate has increased, making the probability of credit card defaults rising. The prediction of credit card default helps banks and financial institutions balance the risk and economic interests, contributes to the stable and healthy development of the financial industry, and plays an important role in bank credit control. Therefore, this paper addresses the credit card default prediction problem by using Random forest, Decision tree, LightGBM, XGBoost, Logistic regression, and Adaboost models to make predictions and compare the results. The outcomes demonstrate that LightGBM algorithm has the most outstanding prediction score, and its AUC value can reach 0.78 and recall rate reaches 0.95. |
| **17** | @article{Aftab2023FraudDO,  title={Fraud Detection of Credit Cards Using Supervised Machine Learning Techniques},  author={Ammar Aftab and Iqra Shahzad and Amna Sajid and Maira Anwar and Nosheen Anwar},  journal={Pakistan Journal of Emerging Science and Technologies (PJEST)},  year={2023}, | [Fraud Detection of Credit Cards Using Supervised Machine Learning Techniques](https://www.semanticscholar.org/paper/Fraud-Detection-of-Credit-Cards-Using-Supervised-Aftab-Shahzad/79feac25a4cecda6b6cc0476e8518dc7ba850b40)  Credit card fraud encompasses illicit activities aimed at unlawfully obtaining confidential information to enable unauthorized individuals to engage in illegal transactions. As technology advances, fraudsters have honed their skills in evading security measures, presenting a formidable challenge in fraud detection. To address this issue, an array of algorithms and analytical techniques has emerged to identify and mitigate instances of fraud. This research aimed to identify the most appropriate supervised machine learning algorithm for credit card fraud detection. Logistic Regression, Random Forest, Support Vector Machine, and Decision Trees were implemented and compared. Due to the imbalanced nature of the dataset, the SMOTE (Synthetic Minority Oversampling Technique) technique was employed to rectify the data imbalance by oversampling the minority class. The performance of the trained models was evaluated using various metrics, including the confusion matrix, accuracy, precision, recall, f1-score, Matthews Correlation Coefficient (MCC), and Area Under the Curve (AUC). The results of the analysis revealed that Random Forests exhibited exceptional performance, achieving an impressive recall score of 84% and surpassing other algorithms. This research provides the groundwork for future investigations involving diverse deep-learning techniques applied to real-time and dynamic datasets, enabling continuous enhancements in fraud detection and prevention mechanisms. |
| **18** | @article{Jakka2023ANC,  title={A novel credit scoring system in financial institutions using artificial intelligence technology},  author={Geethamanikanta Jakka and Amrutanshu Panigrahi and Abhilash Pati and Manmath Nath Das and Jyotsnarani Tripathy},  journal={Journal of Autonomous Intelligence},  year={2023}, | [A novel credit scoring system in financial institutions using artificial intelligence technology](https://www.semanticscholar.org/paper/A-novel-credit-scoring-system-in-financial-using-Jakka-Panigrahi/95194d16d0eae2adc079830306a511a99c797be0)  In order to evaluate a person’s or a company’s creditworthiness, financial institutions must use credit scoring. Traditional credit scoring algorithms frequently rely on manual and rule-based methods, which can be tedious and inaccurate. Recent developments in artificial intelligence (AI) technology have opened up possibilities for creating more reliable and effective credit rating systems. The data are pre-processed, including scaling using the 0–1 normalization method and resolving missing values by imputation. Information gain (IG), gain ratio (GR), and chi-square are three feature selection methodologies covered in the study. While GR normalizes IG by dividing it by the total entropy of the feature, IG quantifies the reduction in total entropy by adding a new feature. Based on chi-squared statistics, the most vital traits are determined using chi-square. This research employs different ML models to develop a hybrid model for credit score prediction. The ML algorithms support vector machine (SVM), neural networks (NNs), decision trees (DTs), random forest (RF), and logistic regression (LR) classifiers are employed here for experiments along with IG, GR, and chi-square feature selection methodologies for credit prediction over Australian and German datasets. The study offers an understanding of the decision-making process for informative characteristics and the functionality of machine learning (ML) in credit prediction tasks. The empirical analysis shows that in the case of the German dataset, the DT with GR feature selection and hyperparameter optimization outperforms SVM and NN with an accuracy of 99.78%. For the Australian dataset, SVM with GR feature selection outperforms NN and DT with an accuracy of 99.98%. |
| **19** | @inproceedings{Amato2022CreditSP,  title={Credit Score Prediction Relying on Machine Learning},  author={Flora Amato and Antonino Ferraro and Antonio Galli and Francesco Moscato and Vincenzo Moscato and Giancarlo Sperl{\'i}},  booktitle={Sistemi Evoluti per Basi di Dati},  year={2022}, | [Credit Score Prediction Relying on Machine Learning](https://www.semanticscholar.org/paper/Credit-Score-Prediction-Relying-on-Machine-Learning-Amato-Ferraro/01bcb642be38e1217ae3a736473bc2f7c53b797d)  Financial institutions use a variety of methodologies to define their commercial and strategic policies, and a significant role is played by credit risk assessment. In recent years, different credit risk assessment services arose, providing Social Lending platforms to connect lenders and borrowers in a direct way without assisting of financial institutions. Despite the pros of these platforms in supporting fundraising process, there are different stems from multiple factors including lack of experience of lenders, missing or uncertain information about the borrower’s credit history. In order to handle these problems, credit risk assessments of financial transactions are usually modeled as a binary problem based on debt repayment, going to apply Machine Learning (ML) techniques. The paper represents an extended abstract of a recent work, where some of the authors performed a benchmarking among the most used credit risk assessment ML models in the field of predicting whether a loan will be repaid in a P2P platform. The experimental analysis is based on a real dataset of Social Lending (Lending Club), going to evaluate several evaluation metrics including AUC, sensitivity, specificity and explainability of the models. |
| **20** | @article{Wang2023CustomerCR,  title={Customer Credit Rating by Machine Learning},  author={Chengyijing Wang and Haining Jiang and Xiaoyan Jin and Ziyu Zhou},  journal={BCP Business \& Management},  year={2023}, | [Customer Credit Rating by Machine Learning](https://www.semanticscholar.org/paper/Customer-Credit-Rating-by-Machine-Learning-Wang-Jiang/28ed167caf95da7fc79fac6c684fe9486ca38be5)  Recently, people's consumption attitudes have also changed, being inclined to spend in advance. Banks and other financial institutions use credit rating models as a tool to evaluate the credit score of individuals, determine whether to grant the loan to the applicant. One of the biggest challenges for the banking industry in assessing the customers’ credit is that it is unlikely to provide a manual review to classify them because of the huge volume of data on applicants. Therefore, it is necessary to establish a suitable and effective credit rating model to help banks evaluate the quality of applicants. This paper focuses on the problems existing in the development of personal credit rating system and tries to find the best solution in the field of personal credit rating system. By selecting independent variables that are highly correlated with delinquency behavior, using different models for testing, and comparing the results of the models, this paper finally draws the conclusion that different algorithms combined by the group decision method can make better decisions. |
| **21** | @article{Dastile2021MakingDL,  title={Making Deep Learning-Based Predictions for Credit Scoring Explainable},  author={Xolani Dastile and Turgay Çelik},  journal={IEEE Access},  year={2021},  volume={9},  pages={50426-50440}, | [Making Deep Learning-Based Predictions for Credit Scoring Explainable](https://www.semanticscholar.org/paper/Making-Deep-Learning-Based-Predictions-for-Credit-Dastile-%C3%87elik/3b3e8a3b16dec52a53a8e23df6947491cc564989)  Credit scoring has become an important risk management tool for money lending institutions. Over the years, statistical and classical machine learning models have been the most researched risk management tools in credit scoring literature, and recently the focus has turned to deep learning models. This transition is due to better performances that are shown by deep learning models in different domains. Despite deep learning models’ superior performances, there is still a need for explaining how these models make their predictions. The non-transparency nature of deep learning models has created a bottleneck for their use in credit scoring. Explanations of decisions are important for lending institutions since it is a requirement for automated decisions that are generated by non-transparent models to be explained. The other issue in using deep learning models, specifically 2D Convolutional Neural Networks (CNNs), in credit scoring is the need to have the data in image format. We propose an explainable deep learning model for credit scoring which can harness the performance benefits offered by deep learning and yet comply with the legislation requirements for the automated decision-making processes. The proposed method converts tabular datasets into images and thus allowing the application of 2D CNNs in credit scoring. Each pixel of the image corresponds to a feature bin of the tabular dataset. The predictions from the 2D CNNs were explained using state-of-the-art explanation methods. Furthermore, explanations were evaluated using a sanity check methodology and also performances of the explanation methods were compared quantitatively. The proposed explainable deep learning model outperforms the other credit scoring methods on publicly available credit scoring datasets. |
| **22** | @article{Kozodoi2021FairnessIC,  title={Fairness in Credit Scoring: Assessment, Implementation and Profit Implications},  author={Nikita Kozodoi and Johannes Jacob and Stefan Lessmann},  journal={ArXiv},  year={2021},  volume={abs/2103.01907}, | [Fairness in Credit Scoring: Assessment, Implementation and Profit Implications](https://www.semanticscholar.org/paper/Fairness-in-Credit-Scoring%3A-Assessment%2C-and-Profit-Kozodoi-Jacob/da0bfa14e348c39d6ae104de6c576ec709f2e115)  The rise of algorithmic decision-making has spawned much research on fair machine learning (ML). Financial institutions use ML for building risk scorecards that support a range of credit-related decisions. Yet, the literature on fair ML in credit scoring is scarce. The paper makes three contributions. First, we revisit statistical fairness criteria and examine their adequacy for credit scoring. Second, we catalog algorithmic options for incorporating fairness goals in the ML model development pipeline. Last, we empirically compare different fairness processors in a profit-oriented credit scoring context using real-world data. The empirical results substantiate the evaluation of fairness measures, identify suitable options to implement fair credit scoring, and clarify the profit-fairness trade-off in lending decisions. We find that multiple fairness criteria can be approximately satisfied at once and recommend separation as a proper criterion for measuring the fairness of a scorecard. We also find fair in-processors to deliver a good balance between profit and fairness and show that algorithmic discrimination can be reduced to a reasonable level at a relatively low cost. The codes corresponding to the paper are available on GitHub1. |
| **23** | @article{Laborda2021FeatureSI,  title={Feature Selection in a Credit Scoring Model},  author={Juan Laborda and Seyong Ryoo},  journal={Mathematics},  year={2021}, | [Feature Selection in a Credit Scoring Model](https://www.semanticscholar.org/paper/Feature-Selection-in-a-Credit-Scoring-Model-Laborda-Ryoo/5a673d120540c69807ae7355ed1b6c2c99b8f29e)  This paper proposes different classification algorithms—logistic regression, support vector machine, K-nearest neighbors, and random forest—in order to identify which candidates are likely to default for a credit scoring model. Three different feature selection methods are used in order to mitigate the overfitting in the curse of dimensionality of these classification algorithms: one filter method (Chi-squared test and correlation coefficients) and two wrapper methods (forward stepwise selection and backward stepwise selection). The performances of these three methods are discussed using two measures, the mean absolute error and the number of selected features. The methodology is applied for a valuable database of Taiwan. The results suggest that forward stepwise selection yields superior performance in each one of the classification algorithms used. The conclusions obtained are related to those in the literature, and their managerial implications are analyzed. |
| **24** | @article{Demajo2020ExplainableAF,  title={Explainable AI for Interpretable Credit Scoring},  author={Lara Marie Demajo and Vince Vella and Alexiei Dingli},  journal={ArXiv},  year={2020},  volume={abs/2012.03749}, | [Explainable AI for Interpretable Credit Scoring](https://www.semanticscholar.org/paper/Explainable-AI-for-Interpretable-Credit-Scoring-Demajo-Vella/6d9125aabc52f723360eac694bf85d73f1f22579)  With the ever-growing achievements in Artificial Intelligence (AI) and the recent boosted enthusiasm in Financial Technology (FinTech), applications such as credit scoring have gained substantial academic interest. Credit scoring helps financial experts make better decisions regarding whether or not to accept a loan application, such that loans with a high probability of default are not accepted. Apart from the noisy and highly imbalanced data challenges faced by such credit scoring models, recent regulations such as the right to explanation' introduced by the General Data Protection Regulation (GDPR) and the Equal Credit Opportunity Act (ECOA) have added the need for model interpretability to ensure that algorithmic decisions are understandable and coherent. An interesting concept that has been recently introduced is eXplainable AI (XAI), which focuses on making black-box models more interpretable. In this work, we present a credit scoring model that is both accurate and interpretable. For classification, state-of-the-art performance on the Home Equity Line of Credit (HELOC) and Lending Club (LC) Datasets is achieved using the Extreme Gradient Boosting (XGBoost) model. The model is then further enhanced with a 360-degree explanation framework, which provides different explanations (i.e. global, local feature-based and local instance-based) that are required by different people in different situations. Evaluation through the use of functionallygrounded, application-grounded and human-grounded analysis show that the explanations provided are simple, consistent as well as satisfy the six predetermined hypotheses testing for correctness, effectiveness, easy understanding, detail sufficiency and trustworthiness. |
| **25** | @inproceedings{Kumar2020ReviewOM,  title={Review of Machine Learning models for Credit Scoring Analysis},  author={Madapuri Rudra Kumar and Vinit Kumar Gunjan},  year={2020}, | [Review of Machine Learning models for Credit Scoring Analysis](https://www.semanticscholar.org/paper/Review-of-Machine-Learning-models-for-Credit-Kumar-Gunjan/569766945340bb024fc818b24292dc045943d949)  Increase in computing power and the deeper usage of the robust computing systems in the financial system is propelling the business growth, improving the operational efficiency of the financial institutions, and increasing the effectiveness of the transaction processing solutions used by the organizations. Problem: Despite that the financial institutions are relying on the credit scoring patterns for analyzing the credit worthiness of the clients, still there are many factors that are imminent for improvement in the credit score evaluation patterns. There is need for improving the pattern to enhance the quality of analysis. Objective: Machine learning is offering immense potential in Fintech space and determining a personal credit score. Organizations by applying deep learning and machine learning techniques can tap individuals who are not being serviced by traditional financial institutions. Methodology: One of the major insights into the system is that the traditional models of banking intelligence solutions are predominantly the programmed models that can align with the information and banking systems that are used by the banks. But in the case of the machine-learning models that rely on algorithmic systems require more integral computation which is intrinsic. Hence, it can be advocated that the models usually need to have some decision lines wherein the dynamic calibration model must be streamlined. Such structure demands the dynamic calibration to have a decision tree system to empower with more integrated model changes. Results: The test analysis of the proposed machine learning model indicates effective and enhanced analysis process compared to the non-machine learning solutions. The model in terms of using various classifiers indicate potential ways in which the solution can be significant. Conclusion: If the systems can be developed to align with more pragmatic terms for analysis, it can help in improving the process conditions of customer profile analysis, wherein the process models have to be developed for comprehensive analysis and the ones that can make a sustainable solution for the credit system management. Originality: The proposed solution is effective and the one conceptualized to improve the credit scoring system patterns. If the model can be improved with more effective parameters and learning metrics, it can be sustainable outcome. Limitations: The model is tested in isolation and not in comparison to any of the existing credit scoring patterns. Only the inputs in terms of shortcomings from the existing models are taken in to account and accordingly the proposed solution is developed. |
| **26** | @article{Provenzano2020MachineLA,  title={Machine Learning approach for Credit Scoring},  author={Angela Rita Provenzano and Daniele Trifir{\`o} and Alessio Datteo and Lorenzo Giada and Nicola Jean and A. Riciputi and Giacomo Le Pera and Maurizio Spadaccino and Luca Massaron and Claudio Nordio},  journal={SSRN Electronic Journal},  year={2020}, | [Machine Learning approach for Credit Scoring](https://www.semanticscholar.org/paper/Machine-Learning-approach-for-Credit-Scoring-Provenzano-Trifir%C3%B2/1a9be760d058a890752423e6a122285cae629b9e)  In this work we build a stack of machine learning models aimed at composing a state-of-the-art credit rating and default prediction system, obtaining excellent out-of-sample performances. Our approach is an excursion through the most recent ML / AI concepts, starting from natural language processes (NLP) applied to economic sectors' (textual) descriptions using embedding and autoencoders (AE), going through the classification of defaultable firms on the base of a wide range of economic features using gradient boosting machines (GBM) and calibrating their probabilities paying due attention to the treatment of unbalanced samples. Finally we assign credit ratings through genetic algorithms (differential evolution, DE). Model interpretability is achieved by implementing recent techniques such as SHAP and LIME, which explain predictions locally in features' space. |
| **27** | @article{Chopra2018ApplicationOE,  title={Application of Ensemble Models in Credit Scoring Models},  author={Anjali Chopra and Priyanka Bhilare},  journal={Business Perspectives and Research},  year={2018},  volume={6},  pages={129 - 141}, | [Application of Ensemble Models in Credit Scoring Models](https://www.semanticscholar.org/paper/Application-of-Ensemble-Models-in-Credit-Scoring-Chopra-Bhilare/7ae71e83242b8ffbcb23413160e6eedfae94eec3)  Abstract Loan default is a serious problem in banking industries. Banking systems have strong processes in place for identification of customers with poor credit risk scores; however, most of the credit scoring models need to be constantly updated with newer variables and statistical techniques for improved accuracy. While totally eliminating default is almost impossible, loan risk teams, however, minimize the rate of default, thereby protecting banks from the adverse effects of loan default. Credit scoring models have used logistic regression and linear discriminant analysis for identification of potential defaulters. Newer and contemporary machine learning techniques have the ability to outperform classic old age techniques. This article aims to conduct empirical analysis on publically available bank loan dataset to study banking loan default using decision tree as the base learner and comparing it with ensemble tree learning techniques such as bagging, boosting, and random forests. The results of the empirical analysis suggest that the gradient boosting model outperforms the base decision tree learner, indicating that ensemble model works better than individual models. The study recommends that the risk team should adopt newer contemporary techniques to achieve better accuracy resulting in effective loan recovery strategies. |
| **28** | @inproceedings{Ha2016CreditSW,  title={Credit scoring with a feature selection approach based deep learning},  author={Van-Sang Ha and Ha-Nam Nguyen},  year={2016}, | [Credit scoring with a feature selection approach based deep learning](https://www.semanticscholar.org/paper/Credit-scoring-with-a-feature-selection-approach-Ha-Nguyen/50ddde187f34a555e9c565b7e046a354ac3c82af)  In financial risk, credit risk management is one of the most important issues in financial decision-making. Reliable credit scoring models are crucial for financial agencies to evaluate credit applications and have been widely studied in the field of machine learning and statistics. Deep learning is a powerful classification tool which is currently an active research area and successfully solves classification problems in many domains. Deep Learning provides training stability, generalization, and scalability with big data. Deep Learning is quickly becoming the algorithm of choice for the highest predictive accuracy. Feature selection is a process of selecting a subset of relevant features, which can decrease the dimensionality, reduce the running time, and improve the accuracy of classifiers. In this study, we constructed a credit scoring model based on deep learning and feature selection to evaluate the applicant’s credit score from the applicant’s input features. Two public datasets, Australia and German credit ones, have been used to test our method. The experimental results of the real world data showed that the proposed method results in a higher prediction rate than a baseline method for some certain datasets and also shows comparable and sometimes better performance than the feature selection methods widely used in credit scoring. |
| **29** | @article{Albareto2016DoesCS,  title={Does Credit Scoring Improve the Selection of Borrowers and Credit Quality?},  author={Giorgio Albareto and Roberto Felici and Enrico Sette},  journal={European Economics: Macroeconomics \& Monetary Economics eJournal},  year={2016}, | [Does Credit Scoring Improve the Selection of Borrowers and Credit Quality?](https://www.semanticscholar.org/paper/Does-Credit-Scoring-Improve-the-Selection-of-and-Albareto-Felici/af3aa3aa4d3ef689ca78f9bc8c0f39bcce4d92da)  This paper studies the effect of credit scoring by banks on bank lending to small businesses by addressing the following questions: does credit scoring increase or decrease the propensity of banks to grant credit? Does it improve the selection of borrowers? Does credit scoring improve or reduce the likelihood that a borrower defaults on its loan? We answer these questions using a unique dataset that collects data from both a targeted survey on credit scoring models and the Central Credit Register. We rely on instrumental variables to control for the potential endogeneity of credit scoring. We find that credit scoring does not change the propensity of banks to grant loans to the generality of borrowers but helps them select borrowers. We also find that credit scoring reduces the likelihood that a borrower defaults, in particular for smaller borrowers and for banks that declare to use credit scoring mainly as a tool to monitor borrowers. These results are homogeneous across bank characteristics such as size, capital, and profitability. Overall our results suggest that credit scoring has a positive effect on the selection of borrowers and on credit performance. |
| **30** | @article{Hooman2016StatisticalAD,  title={Statistical and data mining methods in credit scoring},  author={Alireza Hooman and Govindan Marthandan and Wan Fauziah Wan Yusoff and Mohana Omid and Sasan Karamizadeh},  journal={The Journal of Developing Areas},  year={2016},  volume={50},  pages={371 - 381}, | [Statistical and data mining methods in credit scoring](https://www.semanticscholar.org/paper/Statistical-and-data-mining-methods-in-credit-Hooman-Marthandan/8c939302afce90f75a3068cc3f22ca7502eb0ed9)  The growing interest in the credit industry resulted in credit scoring being developed as an essential component, especially in the credit department of banks that deals with huge sums of credit data. When a bank or a credit corporation is assessing a credit application request, they will have to decide whether to approve or deny it. This necessitates the utilization of credit scoring. Although pioneers attempt to compensate for risks via interest rates, current investigations on financial conditions of different sections of society confirmed that interest could not replace risk assessment, which means that credit risk requires its own specialized assessment. With the assistance of sorting methods, credit scoring simplifies the decision-making process. It is almost impossible to analyze this large amount of data in the context of manpower and economy, although the data mining technique helps alleviate this complexity. Nowadays, there are a lot of data mining methodologies being utilized in the management of credit scoring. However, each method has its advantages and limitations, and there has not been a comprehensive approach in determining the most utilized data mining technique in the context of credit scoring. The major goal of this paper is to provide a complete literature survey on applied data mining methods, such as discriminant analysis, logistic regression, K-nearest neighbor, Bayesian classifier, decision tree, neural network, survival analysis, fuzzy rule-based system, support vector machine, and hybrid methods. These findings will assist researchers in realizing the most suitable approach in evaluating credit scores, pinpoint limitations, enhance them, and propose new approaches with improved capabilities. Finally, the limitations of the new approaches are discussed, and further suitable methods are recommended. |

**BÁO CÁO CHẤM ĐIỂM TÍN DỤNG CỦA KHÁCH HÀNG**

**I, GIỚI THIỆU**

Điểm tín dụng là một phương pháp được sử dụng để đánh giá tính tin cậy của người vay, có thể đó là một cá nhân hoặc một tổ chức; là tiêu chí đầu tiên cần phải xem xét khi làm thủ tục vay ngân hàng hay các công ty tài chính. Điểm tín dụng được thể hiện dưới dạng số điểm, với giá trị càng lớn thì cho thấy người vay có độ tin cậy tín dụng cao hơn. Phân loại điểm tín dụng trong ngân hàng hoặc các tổ chức cho vay là một biện pháp hiệu quả, giúp đưa ra các quyết định cho vay dựa trên nhiều yếu tố như độ tuổi, nghề nghiệp, thu nhập trung bình và lịch sử vay. Từ đó, mà các ngân hàng hay tổ chức tín dụng giảm thiểu được rủi ro, đưa ra quyết định cho vay đúng đắn, hay điều chỉnh lãi suất vay sao cho phù hợp với số điểm từ người vay. Ngoài ra, việc phân loại điểm tín dụng mang lợi nhiều lợi ích đáng kể như: giảm thiểu thời gian trong quá trình duyệt khoản vay, giúp tiết kiệm chi phí, giảm được lượng công việc của ngân viên ngân hàng, đồng thời hạn chế nguy cơ về nợ xấu [24]. Hiểu được tầm quan trọng của việc phân loại điểm tín dụng, các chuyên gia và tổ chức trong lĩnh vực tài chính liên tục phát triển và cải tiến các mô hình chấm điểm tín dụng nhằm nâng cao hiệu quả quá trình đánh giá tín dụng và phản ánh chính xác hơn sự rủi ro của người vay. Mặc dù các mô hình phân loại điểm tín dụng đã tồn tại từ lâu và được sử dụng rộng rãi, song với sự phát triển của công nghệ và dữ liệu, các mô hình này đều được nâng cấp và tối ưu hóa liên tục. Bởi vì chỉ cần có một cải tiến nhỏ trong độ chính xác của các phương pháp xác định điểm tín dụng cũng có thể dẫn đến lợi ích tài chính đáng kể. Từ đó mà việc phát triển các mô hình phân loại điểm tín dụng đã trở thành trọng tâm lớn đối với các cơ quan tài chính nhằm tối ưu hóa lợi nhuận và quản lý rủi ro một cách hiệu quả [1]. Trong những năm qua, các mô hình học máy cổ điển và thống kê đã là công cụ quản lý rủi ro được nghiên cứu nhiều nhất trong các tài liệu phân loại điểm tín dụng và gần đây trọng tâm đã chuyển sang các mô hình học sâu [21]. Gần đây, các mô hình học máy sử dụng phương pháp đánh giá đã cho thấy kết quả đầy hứa hẹn về độ chính xác dự đoán điểm tín dụng [28].

Trong phần tiếp theo, chúng tôi sẽ giới thiệu một số nghiên cứu có liên quan trong Phần II, tiếp đến là phần III với Phương pháp đề xuất. Phần IV sẽ trình bày Thực nghiệm và kết quả, và cuối cùng là Phần V với Kết luận.

**II, NGHIÊN CỨU LIÊN QUAN**

Cho đến nay đã có rất nhiều nghiên cứu đề xuất các phương pháp đánh giá nhằm giải quyết bài toán phân loại điểm tín dụng bằng nhiều mô hình khác nhau. Một nghiên cứu được thực hiện trong năm 2022 đặc biệt tập trung vào việc sử dụng kỹ thuật Machine Learning cho các mô hình chấm điểm tín dụng, phương pháp định lượng được các tổ chức tài chính sử dụng để phân loại khách hàng tiềm năng là người vay tốt hay xấu. Cách tiếp cận này dựa trên điểm số định lượng sử dụng thẻ điểm ứng dụng ở giai đoạn khởi tạo khoản vay [2].

Trong nghiên cứu số [28], tác giả của bài viết đã xây dựng mô hình chấm điểm tín dụng dựa trên việc học sâu và lựa chọn tính năng để đánh giá điểm tín dụng của người nộp đơn từ các đặc điểm đầu vào của người nộp đơn. Hai bộ dữ liệu công khai, dữ liệu tín dụng của Úc và Đức, đã được sử dụng để kiểm tra, đánh giá các phương pháp. Kết quả thử nghiệm dữ liệu trong phương pháp được đề xuất mang lại tỷ lệ dự đoán cao hơn phương pháp cơ sở đối với một số bộ dữ liệu nhất định và cũng cho thấy hiệu suất tương đương.

Ngoài ra, một bài nghiên cứu được viết vào năm 2022 là so sánh trực tiếp Gradient Boosting Machines và Deep Learning về dự đoán độ chính xác để phân loại tệp khách hàng. Ba tập dữ liệu riêng biệt với các tính năng khác nhau đã được sử dụng để giải thích khả năng lựa chọn hay sức mạnh của mô hình dựa trên các đặc điểm của tập dữ liệu cơ bản. Kết quả cho thấy nghiên cứu này làm sáng tỏ khả năng dự đoán và tính hữu ích của cả hai mô hình quản lý rủi ro tín dụng trong thị trường cho vay – đặc biệt là chấm điểm tín dụng [5].

Gần đây nhất, một nghiên cứu được công bố vào năm 2023 với mục đích là đề xuất một mô hình tín dụng tổng thể không đồng nhất, có khả năng thích ứng, tích hợp các mô hình XGBoost và Máy Vector hỗ trợ để cải thiện độ chính xác và độ tin cậy của các mô hình chấm điểm tín dụng và đánh giá rủi ro. Phương pháp này sử dụng các kỹ thuật học máy để nhận biết các mẫu và xu hướng từ dữ liệu trong quá khứ nhằm dự đoán các sự kiện xảy ra trong tương lai [14].