

The best machine learning model for fraud detection on e-platforms: a systematic literature review

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ABSTRACT

The internet has been instrumental in the development and facilitation of online payment systems. However, its associated fraudulent activities on e-platforms cannot be overlooked. As a result, there has been a growing interest in the application of machine learning (ML) algorithms for fraud detection on financial e-platforms. The goal of this research is to identify common types of fraud on financial e-platform, highlight different machine learning algorithms employed in fraud detection, and derive the best machine learning algorithms for fraud detection on e-platforms. To achieve this goal, the research followed a nine steps systematic review approach to retrieve Journals and conference publications from science direct, Google Scholar and IEEE Xplore between 2018 and 2023. Out of 2,071 articles identified and screened, 44 publications (23 articles and 21 conference proceedings) satisfied the inclusion criteria for further analysis. The random forest algorithm turned out to be the best ML algorithm because it ranked first in the frequency of usage analysis and ranked first in the performance analysis with an average accuracy of 96.67%. Overall, this review has identified the kinds of fraud on financial e-platforms, and proclaimed the best and least ML algorithm for fraud detection on financial e-platform. This can help guide future research and inform the development of more effective fraud detection systems.

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1. INTRODUCTION

The advancement in technology and the evolution of the internet have paved the way for the establishment of modern services, including e-commerce and financial transactions. Traditional buyer-seller relationships and the shopping experience for many consumers have been significantly altered by e-commerce [1]. E-commerce and the widespread use of online banking have contributed to a recent uptick in the volume of monetary transactions. The Internet has been instrumental in the development and facilitation of online payment systems. However, this increased convenience presents several obstacles, the most

significant of which is the problem of fraudulent activities on these e-platforms [2]. Presently, online financial fraud has become a more intricate and difficult challenge to solve [3].

The most typical forms of fraud that can be committed on online systems that may cost consumers and e-commerce sites a lot of money include Payment fraud (criminals commit payment fraud by either stealing financial details or forging credentials to use for online purchases). Account takeover fraud (Fraudsters impersonate a real user in order to make illegal purchases or obtain sensitive information). Phishing scams (scammers employ phishing emails, texts, and social media posts to fool consumers into divulging sensitive information by making it look to come from a trusted organization, such as a bank or online retailer). Identity theft (Theft of sensitive personal information, such as social security numbers or credit card data, can lead to the opening of fake accounts and the making of fraudulent purchases). Chargeback fraud (To commit chargeback fraud, a user must erroneously assert that they did not get the purchased products or services).

We must learn to recognize the red flags of online fraud and take preventative measures. The traditional methods of fraud detection on e-platforms, such as rule-based systems and manual review processes, are often unable to keep up with the rapidly evolving tactics of fraudsters. These methods are also resource-intensive and time-consuming, making them inefficient and often ineffective in detecting and preventing fraud [4]. Consequently, there has been a growing interest in the application of machine learning (ML) models for fraud detection on e-platforms. The goal of this research is to identify common types of fraud on financial e-platform, highlight which ML model are used for fraud detection on financial e-platforms and also ascertain the best ML for fraud detection on e-platforms in terms of performance metrics.

A machine learning algorithm is a type of algorithm that can learn from data and perform a task without being explicitly programmed to do so. These algorithms are "soft coded" in the sense that they improve the task at hand through iteratively changing or adapting their underlying structure [5]. By measuring prediction mistakes during the training phase, machine learning has an intelligent system that allows it to continuously learn [6]. Machine learning has proven to be a promising approach for fraud detection in e-commerce due to its ability to learn from large amounts of data and identify patterns that traditional methods may miss. By leveraging the power of ML, e-commerce platforms can build more effective fraud detection systems that are faster, more accurate, and less resource-intensive.

According to Naqa *et al.* [5], depending on how the data is labeled, machine learning can be categorized as supervised, semi-supervised, or unsupervised. Supervised learning is the process of utilizing labeled datasets to train algorithms that effectively classify data or predict outcomes (e.g., classification and regression). Semi-supervised learning is a hybrid of supervised and unsupervised learning in which a portion of the data is partially labeled and the labeled portion is used to infer the unlabeled portion. In unsupervised learning, the learning system receives only input samples (e.g., clustering and estimation of probability density function).

However, the use of ML models for fraud detection on e-platforms is not without its own set of challenges. The performance of these models depends on the quality and size of the training data, the choice of appropriate features and algorithms, and the complexity of the fraud detection problem. To gain a better understanding of machine learning models for fraud detection on e-platforms, a systematic literature review is necessary. Such a review can provide an overview of the existing research on the topic, identify the different types of machine learning models that have been used for fraud detection, and highlight the best models. In this regard, the current study was conducted to perform a systematic literature review to analyze research studies to identify the common types of fraud on financial e-platforms and to determine the best machine learning algorithms in terms of performance metrics that have been used for fraud detection on e-platforms.

2. METHOD

This section describes in detail how we carried out the methodological literature review. Based on the advantages of systematic literature review (SLR) such as comprehensiveness, reliability and unbiased coverage of relevant studies [7], this research adopted the SLR steps in [8] to conduct the SLR by following the key steps in Figure 1. The application of Figure 1 to our research, are further described in subsections 2.1-2.9.

2.1. Defining the research questions

According to Thilakaratne *et al.* [8], the first stage of SLR is to establish appropriate research questions. These questions should be focused, clear and guide what we wanted to find out from the research. In this regard, we derived the following three research questions (RQs) from our pre-planned topic:

RQ1: What are the common types of fraud on e-platforms?

RQ2: Which machine learning algorithms are used for Fraud detection on e-platforms?

RQ3: What are the best machine learning algorithms used on e-platforms for fraud detection?

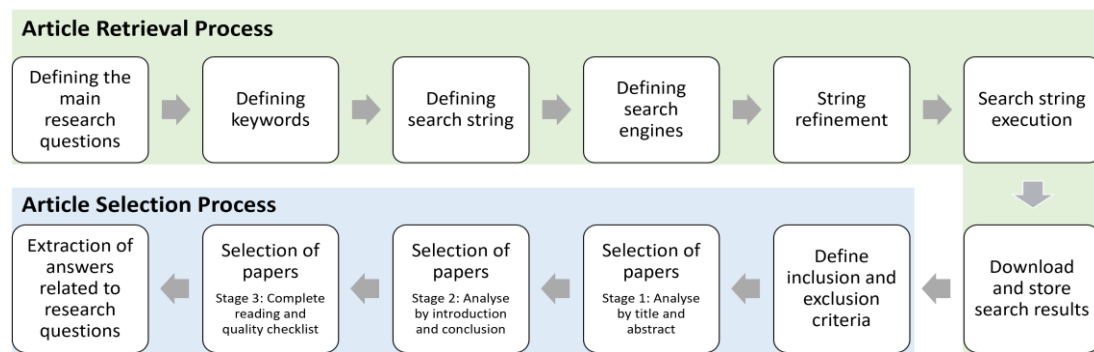


Figure 1. Systematic literature review process [8]

2.2. Defining concepts and keywords

In the second step, we then came out with the following three concepts in relation to the topic and research questions;

Concept 1: “Machine learning models”

Concept 2: “Fraud detection”

Concept 3: “e-platforms”

By considering the synonyms, other spelling variations and abbreviations of the concepts, we then derived the following keywords: “Machine Learning models”, “Machine Learning techniques”, “Machine learning algorithms”, “fraud detection”, “e-platforms”, and electronic platforms.

2.3. Defining search string

The above keywords were then merged using control vocabulary or Boolean operators. Thus, using the “population, intervention, comparison, outcome” (PICO) and the “MESH” approach, we came out with the following search string as shown in Figure 2.

“Machine Learning models” OR “Machine learning algorithms” OR “Machine Learning techniques” AND
“fraud detection” AND “e-platforms” OR “electronic-platforms.”

Figure 2. Search string

2.4. Defining search engines

In this sub-section 4, search engines were defined. Our methodology used a suitable selection of databases to obtain comprehensive coverage of the literature and to raise the likelihood of discovering highly suitable articles. Consequently, the following electronic literature databases were included in our search; ScienceDirect, Google Scholar, and IEEEExplore.

2.5. String refinement

The string defined in sub-section 2.3 was tested in one of the search engines (Google Scholar). Once the string was applied, we verified if the returned papers were relevant. Known papers that are potential candidates for primary studies in this review (which exist on these engines) appeared in the search. In cases where there were no relevant results, the search string was parsed again to be calibrated. At the end, the refinement of the search criteria was done in each database.

2.6. Search string execution and search results

Once the search string was defined, it was adapted to each of the selected three search engines. As the search went on, the search results were documented, the number of articles each search returned, and the date of execution were also documented. Figure 3 demonstrated the resulting preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram derived from the research.

Thus, at the end of searching all the three databases, we found a total of 2,071 articles. These articles were imported into Rayaana to begin the systematic review process. First of all, 35 out of the 2,071 articles were de-duplicated in the “Rayaan” web tool. The remaining 2,036 articles were further screened on a title

and abstract basis in Rayyan. There was an initial conflict on 20 articles which was subsequently resolved. A total of 1,894 records were further excluded. The remaining 142 included articles were exported from “Rayyan” into Microsoft Excel for further screening based on their introductions, methodologies, findings, and conclusions. The eligibility criteria used is defined in the following section.

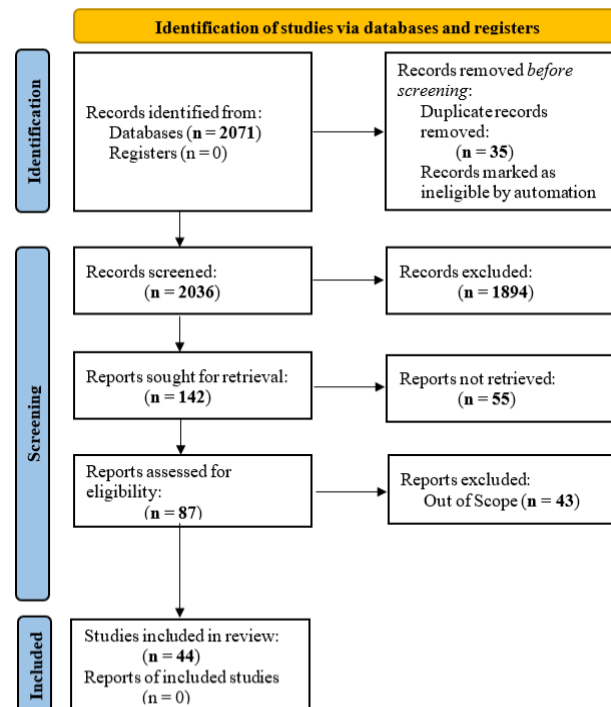


Figure 3. PRISMA flow diagram

2.7. Defining inclusion and exclusion criteria

In sub-section 7, we concentrated on examining several factors that affect how financial e-platforms operate. The chosen approach enabled us to list and categorize different machine learning models currently in use for detecting fraud on financial e-platforms. The review also included the evaluation of the effectiveness of different machine learning algorithms in detecting fraud on financial e-platforms. The approach also identified relevant data using the inclusion and exclusion criteria and in summarizing the findings.

2.8. Selection of papers

“Rayyan” web tool which is designed to help researchers working on systematic reviews, scoping reviews, and other knowledge synthesis projects, was used in this review for screening and coding of studies. In order to select the relevant papers for the actual analysis we went through three stages of analyses. First, we conducted title and abstract screening of the relevant articles by marking them in Rayyan as either “included”, “excluded” or “doubtful”. Secondly, in order to refine the selection in the previous stage, the introductions and conclusions of the selected papers were analysed. Finally, the third stage of the analyses involved complete reading of selected articles, quality check and comparative analysis.

Thus, the 142 articles exported to Microsoft Excel were subjected to the following eligibility criteria: i) Reports not retrieved (unavailability of full text) and ii) Reports or articles that are out of scope.

The screening results indicated that out of the total of 142 papers, 55 full-text papers were unavailable and 43 papers were out of scope. The remaining papers included for further analyses were 44.

2.9. Extraction of answers to research questions

At this stage, the research questions were answered by analyzing the selected papers in the previous step with the aid of a spreadsheet. As we read each of the selected papers, the possible answers extracted was posted directly in the spreadsheet. Figure 4 shows a snapshot of the spreadsheet used for the final stage of screening while the results of the research are presented in the Findings and discussions section.

No.	Title	authors	year	Objectives	Abstract	Methodology	Types of Fraud	Machine Learning Algorithms Used	Findings/Outcomes	Remarks
1	Credit Card Fraud Detection Using Conditional Tabular Generative Adversarial Networks (CT-GAN) and Supervised Machine Learning Techniques	Pali, Tushar	2021	To evaluate the effectiveness of using CT-GAN and machine learning techniques in improving the accuracy of credit card fraud detection, in comparison to other state-of-the-art techniques for handling class imbalance challenges	Credit card fraud has been a major concern for financial institutions and business stakeholders for a long time and due to its ever-increasing nature, it has been a global topic of interest for researchers. Machine learning has proved to be one of the promising approaches for the detection and prediction of frauds. Despite having various advantages, there is no ideal model to handle this task due to the various factors involved. On the other hand, the class imbalance is one of the major and frequently occurring challenges while dealing with fraud detection tasks which hamper the model performance. There are several previously explored studies combining machine learning algorithms with various data pre-processing techniques to handle class imbalance challenges. To take this research further we have used a novel approach of combining supervised machine learning algorithms like Logistic Regression, Random Forest, XGBoost with Conditional Tabular Generative Adversarial Networks (CT-GAN) for balancing skewed data by data augmentation. We have used the SelectKBest feature selection method for selecting the most significant features for our analysis. After testing the proposed technique on our machine learning algorithms which are trained on both unbalanced and balanced data, we have observed a significant increase in model performance in terms of F1-score, recall, AUC score and G-mean. The results show that the Random Forest model outperforms other models in all terms with 100% recall value followed by XGBoost having recall of 81% after applying our proposed technique whereas Logistic Regression has shown the	We utilized a hybrid combination of a data modelling method-CT-GAN and feature selection technique-SelectKBest in this study to handle the class imbalance challenge while using machine learning models and developed 3 models using this approach.	credit card fraud detection	Logistic regression, Random Forest, XGBoost with Conditional Tabular Generative Adversarial Networks (CT-GAN) for balancing skewed data by data augmentation	The results show that the Random Forest model outperforms other models in all terms with a 100% recall value followed by XGBoost having a recall of 81% after applying our proposed technique whereas Logistic Regression has shown the most significant increase in performance from 78% recall to	
2	CREDIT CARD FRAUD DETECTION USING DEEP LEARNING	Dian, Kamilia, Lailani, Laouani, Mohamed, Azzou	2022	aims to use deep learning to detect fraud in online transactions	As the number of online businesses is increasing continuously, millions of individuals have switched their preferences toward the online experience as it requires less effort. With this rise comes fraud. Scammers always find techniques to use other people's data for unauthorized online purchases. Therefore, this capstone project aims to use deep learning to detect fraud in online transactions. While there exist several machine learning classification models to perform the fraud detection task, deep learning has demonstrated promising results in terms of accuracy, precision, and recall. For this project, the Long Short-Term Memory (LSTM) model will be employed to achieve maximum performance. However, before feeding the data into the model to train, it is important to balance it and normalize it. The dataset used in this project is retrieved from Kaggle.com, and it contains 284,807 online transactions made by European credit cardholders. The LSTM model reached a prediction accuracy of 99.94%, a precision of 99.98%, and a recall of 99.99%.	Data Analysis and modeling Long Short-Term Memory (LSTM) model will be employed to achieve maximum performance	Detection of fraud in online credit card transactions	deep learning	The LSTM model reached a prediction accuracy of 99.94%, a precision of 99.98%, and a recall of 99.99%.	

Figure 4. Snapshot of screening spreadsheet

3. RESULTS AND DISCUSSION

This section gives a detailed discussion of the results of the analysis. The initial database search returned a total of 2,071 results. After applying the selection and eligibility criteria, 44 publications were left for detailed analysis and the results are presented in the following sub-sections.

3.1. Common types of fraud on e-platforms

The first research question was to investigate the common types of fraud on e-platforms, after a thorough analysis of the 44 articles included in the studies, the result revealed that the common types of electronic frauds on financial e-platforms are: Credit card fraud, banking transaction fraud and E-commerce fraud with frequency of 36, 5 and 3 respectively. Therefore, credit card fraud is the most prevalent form of fraud on e-platforms. Figure 5 and Table 1 summarizes the results.

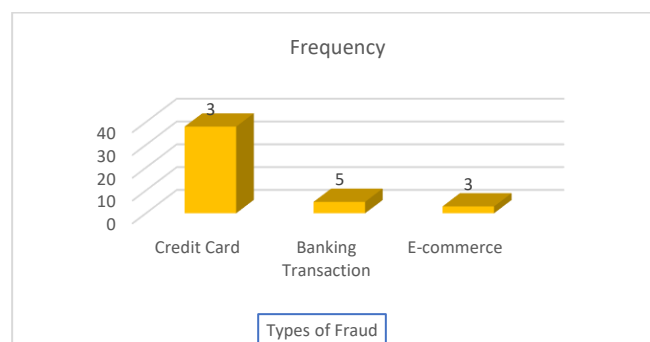


Figure 5. Types of electronic fraud

Table 1. Types of electronic fraud

No.	Type of Fraud	Frequency	Percentage (%)
1	Credit card	36	81.82
2	Banking transaction	5	11.36
	E-commerce	3	6.82

3.2. Machine learning algorithms used for fraud detection on e-platforms

The second research question was to find out which machine learning algorithms are used for fraud detection on e-platforms. Table 2 is the summary of results obtained from the 44 articles we worked with. It

The best machine learning model for fraud detection on e-platforms: ... (Alimatu – Saadia Yussiff)

is evident from Table 2 and Figure 6 that 23 different machine learning models were used in the 44 different publications we worked with.

Table 2. Different machine learning algorithms for fraud detection

No.	Machine Learning (ML) Algorithm	Reference	Frequency of Usage
1	Long Short-Term Memory (LSTM)	[9]-[11]	3
2	Logistic Regression (LR)	[10], [11], [12], [13]-[28]	19
3	Random Forest (RF)	[10], [12], [14], [16]-[23], [25]-[39]	27
4	XGBoost	[13], [21], [20], [34], [39], [40]	6
5	AdaBoost	[9], [29], [20], [43], [44], [39], [41], [42]	9
6	Support Vector Machine (SVM)	[12], [14]-[16], [18], [19], [25], [26], [28], [30], [31], [45]-[48]	15
7	Naïve Bayes (NB)	[10], [14], [24]-[26], [30], [48], [49]	8
8	K-Nearest Neighbour (KNN)	[10], [11], [12], [16], [18], [20], [24]-[26], [30], [47], [49]	12
9	Multi-Layer Perceptron (MLP)	[10], [20], [31], [49]	4
10	Complement Naïve Bayes	[10]	1
11	Gaussian Naïve Bayes	[10], [18], [20], [49]	4
12	Bernouli Naïve Bayes	[10]	1
13	Light Gradient Boosting Machine (LGBM)	[10], [13], [15]	3
14	Decision Tree	[10], [12], [14], [16], [17], [20]-[23], [27], [34], [38]	12
15	Gradient Boost	[14], [20], [22], [29]	4
16	Convolutional Neural Network (CNN)	[9], [11], [18], [44]	4
17	Isolation Forest	[31], [50],	2
18	Artificial Neural Network (ANN)	[14], [19], [22], [24], [47], [46], [51]	7
19	k-means	[18], [44], [51],	3
20	Linear Regression	[34]	1
21	J48 Algorithm	[37]	1
22	Perceptron	[10], [24], [25]	3
23	CatBoost	[39]	1

Figure 6 also illustrates that the least used models are complement naïve Bayes, Bernoulli naïve Bayes, isolation forest, linear regression, J48, and CatBoost algorithms. Other algorithms like K-nearest neighbor (KNN), decision tree, support vector machine (SVM), logistic regression, and random forest fell within the top five with random forest being the most used machine learning algorithm for fraud detection.

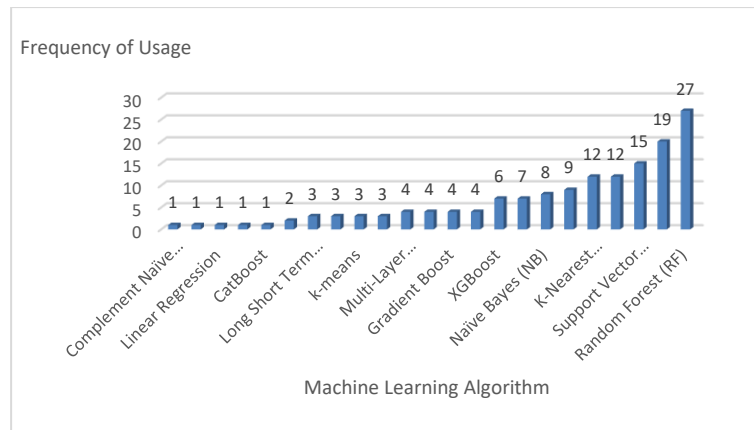


Figure 6. Different machine learning algorithms for fraud detection

3.3. The best machine learning algorithms used on e-platforms for fraud detection

Research question three was to determine the best machine learning algorithms used on e-platforms for fraud detection. In order to answer this question, we compared and analyzed the performance of the top five machine learning algorithms based on their frequency of usage. The performance metric used in this review is accuracy. Since most of the authors used a common dataset (transactions made by credit cards in September 2013 by European cardholders.), it will be prudent to analyze and compare their performances. The results from the analysis are presented in Figure 7.

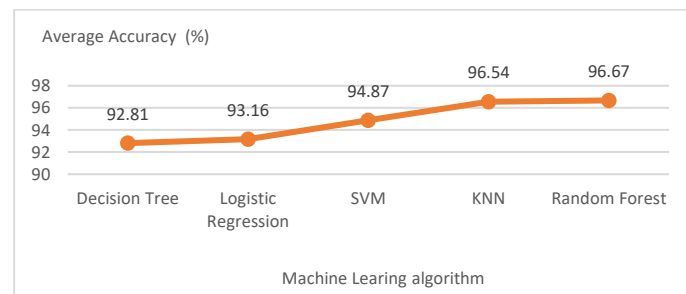


Figure 7. Average accuracies of top 5 (frequency of usage) ML algorithms

Results from Figure 7 demonstrated that the Decision Tree algorithm performs the least with an average accuracy of 92.81%. This is followed by logistic regression, SVM, KNN, and random forest algorithm with an average accuracy of 93.16, 94.87, 96.54, and 96.67 respectively. The result also indicated that, even though the KNN ranked 4th in terms of frequency of usage as shown in Table 2, it ranked 2nd in terms of performance with an accuracy of 96.54% as illustrated in Figure 7. The logistic regression algorithm ranked 2nd in terms of frequency of usage but it is the 4th best in terms of performance with an average accuracy of 93.16%. Also, The SVM algorithm ranked 3rd in terms of frequency of usage and ranked 3rd in terms of performance with an average accuracy of 94.87%. More importantly, the random forest algorithm ranked 1st in terms of frequency of usage and ranked 1st in terms of performance with an average accuracy of 96.67%.

4. CONCLUSION

This research revealed that credit card fraud is more common in the area of financial fraud on e-platforms. Based on our systematic literature review credit card fraud accounted for 82.61% of the financial fraud cases on e-platforms. Secondly, this review identified 23 different machine-learning algorithms that were used to detect fraud on e-platforms. Notable amongst them is random forest which had the highest frequency of usage followed by logistic regression and support vector machine, whereas algorithms like linear regression, Bernouli naïve Bayes, J48 algorithm, and CatBoost had the lowest frequency of usage. The research also revealed that the predominant usage of a model does not guarantee its superior performance, as exemplified by the cases of KNN and logistic regression. The logistic regression algorithm ranked 2nd in terms of frequency of usage but ranked 4th best in terms of performance with an average accuracy of 93.16%. On the contrary, the KNN ranked 4th in terms of frequency of usage but ranked 2nd in terms of performance with an accuracy of 96.54%. The random forest algorithm turned out to be the best machine learning algorithm as it is ranked first in the frequency of usage analysis and first in the performance analysis with an average accuracy of 96.67%. Hence, the random forest algorithm should be considered ahead of other machine learning algorithms for such fraud detection analysis on e-platforms. By identifying the strengths and weaknesses of different approaches, this review can help guide future research and inform the development of more effective fraud detection systems. Overall, this review has identified the kinds of fraud on financial e-platforms, and proclaimed the best and least ML algorithm for fraud detection on financial e-platform. This can help guide future research and inform the development of more effective fraud detection systems. This review was limited to financial fraud detection and accuracy was the only performance metric used for the comparative analysis. Future work could therefore consider performance metrics like recall and precision in the comparative analysis.

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