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Detecting Fraudulent Firms in External Audits Using Artificial Neural Networks: An Experimental Study on the UCI Audit Risk Dataset

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Abstract*: External auditors face the menace of financial statement fraud, making it one of their biggest risks. Common methods of audit sample would not be suited for the complexities of today's vast amounts of financial data. This research study will evaluate if artificial neural networks (ANNs) can classify firms as fraudulent or non-fraudulent using the UCI Machine Learning Repository's Audit Risk dataset. This dataset has a total of 776 records of firm data with 27 attributes collected by an external audit office. During the data preparation stages for this project there was an issue with data leakage; the following attributes: Risk_A , Risk_F, Inherent_Risk, Control_Risk, Detection_Risk and Audit_Risk were found to be mathematically deterministic functions of the outcome variable Risk. Consequently, these attributes were removed prior to modeling to ensure that the resulting classification task would be valid and generalizable. Normalization of the remaining 16 attributes was completed using min-max scaling and utilized to develop a feedforward neural network with a single hidden layer of five neurons established in the JustNN program. The backpropagation training utilized a learning rate of 0.6 with a momentum value of 0.8 with training automatically stopping when the average training error was equal to or less than 0.01.*

Keywords*:* Artificial Neural Networks, Fraud Detection, External Audit, Audit Risk, Data Leakage, Feature Selection, Classification, Machine Learning, UCI Dataset, JustNN.

1. Introduction

External auditing is an essential component for financial accountability since it provides independent verification that a company's financial statements do not contain material misstatements due to error or fraud. Traditionally, auditors have used statistical sampling, checklists and professional expertise to identify companies or transactions that required extra scrutiny. The shift towards larger quantities and greater levels of complexity in financial data has revealed the limitations of traditional manual audit risk assessment techniques; therefore, there is an increased interest in using data-driven and artificial intelligence methodologies to assess audit risk.

The use of artificial neural networks ("ANNs") offers characteristics that make them well-suited to accomplishing this task. ANNs have similar structures to biological neural systems, and as such, are capable of developing complex, non-linear relationships between financial risk indicators without the analyst needing to predefine those relationships. Through the iterative adjustment of their internal weights, unlike traditional statistical modeling techniques, ANNs can learn from subtle differences in patterns distinguishing fraudulent companies versus non-fraudulent companies.

2. Objectives

This paper examines the use of multiple neural networks to create a classification model using the UCI Audit Risk dataset for assessing the audit risk of an entity.

The objectives of this study are:

1. To prepare (pre-process) the UCI Audit Risk dataset so that it can be used in a neural network-based classification task; this includes addressing categorical variables, missing values, and scaling features on to a similar range.

2. To identify and remove any unnecessary attributes from the dataset that may cause data leakage.

3. To create, train, and assess a feed forward neural network that can classify an entity as fraud (high risk) or non-fraud (low risk).

4. To evaluate the performance of the trained neural network using both validation accuracy and error metrics.

5. To identify which input attributes are the most significant in terms of contributing to the neural network's classification.

6. To discuss the implications of the results of this study, both practical and methodological, for machine learning practitioners and auditing practitioners.

3. Problem Statement

The process of manually performing an audit risk assessment is lengthy, vulnerable to human error, and lacks scalability when evaluating numerous firms or transaction sets. Conversely, developing a model of audit-related data using machine learning models has significant challenges as audit datasets often include derived/composite variables (e.g., a precalculated risk score) that draw their value from the same underlying audit data, which can create complications for any model's ability to accurately predict the actual outcome that the models are designed to evaluate.

For that reason, if derived/composite variables are used as inputs to a model, without sufficient review for the possibility of data leakage, the model created will appear to be an extremely reliable and valid predictor, when in actuality, it will have learned a trivial, not generally applicable method of prediction and not an actual predictive relationship.

This creates two fundamental concerns related to the development of an ANN-based model of whether or not firms are fraudulent or abusive: Building a neural network-based predictor of whether or not firms are abusing the auditing profession by using only legitimate raw audit-related indicators, and Correctly identifying and eliminating any data leaks from the audit-related data, which would otherwise yield results that are misleadingly positive, thus having no practical utility.

4. Literature Review

Data employed in this investigation stems from a case study conducted for use by an external auditing company based upon annual data gathered across fourteen sectors from seven hundred seventy-seven (777) companies; the goal being to analyze the value of machine learning methods to support credit risk assessment in auditing. Data folder contained in original authors' work provided the authors (in the original study) to apply their original implementation of Particle Swam Optimization (PSO) used to select relevant features to compare ten different model types against one another based upon two metrics: Accuracy (ACC), Sensitivity (SEN), Specificity (SPEC), as well as Area Under Curve (AUC). Following the completion of this research effort, authors obtained additional funding to conduct a follow-up project extending prior research to investigate a multi-criteria ensemble predictive performance methodology (TOPSIS) based on using several classifiers predicting which companies would commit fraud prior to the commencement of audit work.

Additionally, a similar dataset has been used in other studies beyond what was written by the original authors. For example: A 2024 research article utilized data from the UCI audit database containing 776 records with a total of 27 characteristics associated with each record to examine the direct application of machine learning to this dataset. Similarly, however with some different criteria, this study also used feature elimination in selecting specific characteristics for machine learning analyses by removing 13 of the 27 original (characteristics/Characteristics) because they did not impact analysis based upon either the predictive accuracy of their models or the "important characteristic" feature elimination.

There is a lot of research on the use of AI (Artificial Intelligence) and Machine Learning (ML) to detect fraud in the financial world, including numerous studies using various tools such as artificial neural networks and other Machine Learning techniques to detect financial fraud. In one example study investigating ways to improve the accuracy of detecting fraudulent financial statement information utilized a hybrid Decision Tree model as the primary method of detection and ultimately achieved an overall accuracy rate of around 88 percent, with a fraud detection-specific accuracy rate of nearly 93 percent. In another example study that analyzed fraud detection within each financial transaction (identified by transaction type using labels) included comparing Logistic Regression, Random Forest, Gradient Boosted Trees (XGBoost) and Convolutional Neural Networks (CNN) for their ability to accurately predict fraud on an individual basis using labelled financial transactions, and the Gradient Boosted XGBoost model outperformed all other models evaluated in identifying fraud, achieving an overall accuracy rate of approximately 95 percent.

5. Methodology

5.1 Dataset.

The UCI Audit Risk dataset was used, consisting of 776 usable records (after cleaning) across firms from multiple sectors, with a binary target variable, Risk (0 = low risk, 1 = high risk of fraud).

5.2 Data Cleaning.

Three preprocessing issues were identified and resolved prior to modelling:

- A duplicated column name (Score_B appeared twice in the raw file) was resolved by renaming the second occurrence to Score_C.

- Three records contained district names (text strings) instead of numeric codes in the LOCATION_ID field; these were mapped to new unique numeric identifiers.
- One missing value in the Money_Value field was imputed using the column median.

5.3 Data Leakage Removal.

Analysis of the dataset's internal structure revealed that the attribute Inherent_Risk is an exact sum of six other attributes (Risk_A through Risk_F), and that Audit_Risk is an exact product of Inherent_Risk, Control_Risk, and Detection_Risk. Furthermore, the binary target Risk was found to be a deterministic threshold function of Audit_Risk (Risk = 1 if Audit_Risk > 1.0), yielding 100% classification accuracy when Audit_Risk was used as a predictor. Because these ten attributes (Risk_A–Risk_F, Inherent_Risk, Control_Risk, Detection_Risk, Audit_Risk) would allow the model to "solve" the classification task through simple arithmetic rather than genuine pattern learning, all ten were removed, leaving sixteen legitimate input attributes: Sector_score, LOCATION_ID, PARA_A, Score_A, PARA_B, Score_B, TOTAL, numbers, Score_C, Money_Value, Score_MV, District_Loss, PROB, History, Prob, and Score.

5.4 Normalization.

All sixteen input attributes were rescaled to the [0, 1] range using min-max normalization, calculated independently for each column, to ensure comparable feature magnitudes during backpropagation and to accelerate convergence.

5.5 Train/Validation Split. The dataset was split into training and validation.

5.6 Network Architecture and Training.

A feed-forward, fully connected neural network was constructed and trained in JustNN.

5.7 Evaluation Metrics.

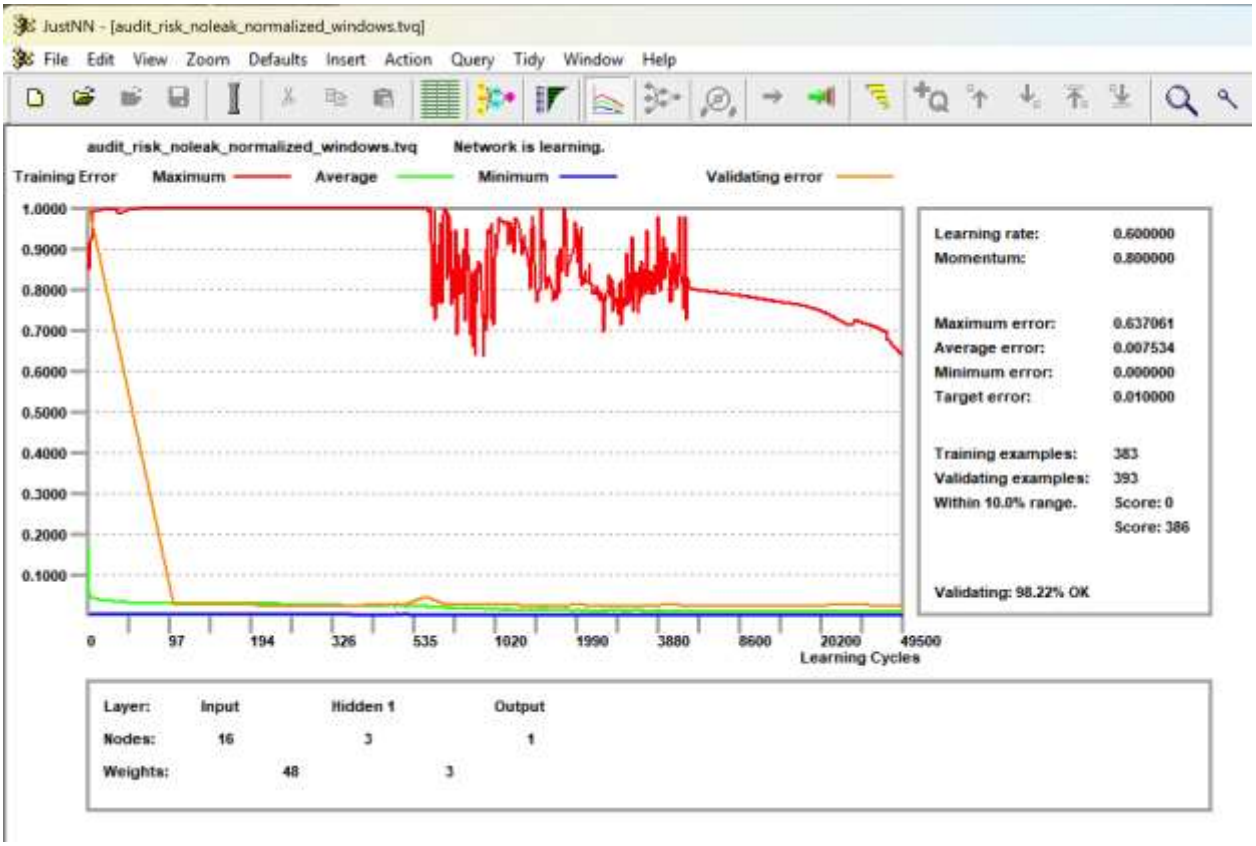
Model performance was assessed using the average and maximum training error, the average validation error, and validation accuracy.

6. Results

Two training runs were conducted to evaluate the consistency of the model:

Metric	Trial 1	Trial 2
Training examples	383	577
Validation examples	393	199
Average training error	0.007534	0.009960
Target error	0.01	0.01
Validation accuracy	98.22% (386 / 393)	97.49% (194/199)

The two trials used different random splits for the training and validation and the hidden layer sizes differ somewhat, but they both reached very similar validation accuracies (97.49% to 98.22%). Hence, this indicates that the model performs reliably in its own right and not just because of how the data was split.



7. Discussion

These findings provide support for the hypothesis that a simple feed-forward neural network, trained on 16 independent audit measures, will accurately classify a firm's fraud status, as either fraudulent or non-fraudulent, with a 97–98% validation accuracy rate. Such findings are within, and perhaps exceed, those in prior studies using more sophisticated ensemble or hybrid models and similar audit fraud datasets; therefore, it appears that when a dataset is appropriately cleaned, even a small ANN can perform comparably to a much larger and more complex ANN.

The variables used to train the ANN, the most significant predictor of firm fraud status was the amount of money associated with a particular class of audit paragraph findings (PARA_A) and is congruent with the theoretical foundation of auditing because the value of a discrepancy is one of the most accepted indicators of risk according to professional auditing standards. Also, Sector_score, which reflects the historical risk associated with an industry sector, conforms with the risk assessment models that lend more weight to the level of risk associated with an industry level than any other variable included in an audit decision model.

8. Conclusion:

The present study has demonstrated that using an artificial neural network trained on clean, non-leaky audit indicators from the UCI Audit Risk dataset can accurately discern fraudulent from non-fraudulent firms at about a 97 - 98% validation accuracy rate. The most influential predictors were found to include the monetary magnitude of audit findings (PARA_A) and the historical sector-level risk score, both of which conform to established audit theory. Moreover, the present study has revealed that there were significant data leakage problems in the raw data; many of the attributes had been mathematically derived from the target variable, and identifying and removing those attributes has been critical in developing a valid and generalizable model. Therefore, at least in part, the success or failure of a machine learning application in auditing is dependent not only on the architecture and training parameters of the network but also and, perhaps, more importantly, on the preparation of the data used for training, which must be rigorously prepared and based upon knowledge of the domain.

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