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An ANN-based auditor decision support system using Benford's law

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ABSTRACT

While there is a growing professional interest on the application of Benford's law and "digit analysis" in financial fraud detection, there has been relatively little academic research to demonstrate its efficacy as a decision support tool in the context of an analytical review procedure pertaining to a financial audit. We conduct a numerical study using a genetically optimized artificial neural network. Building on an earlier work by others of a similar nature, we assess the benefits of Benford's law as a useful classifier in segregating naturally occurring (i.e. non-concocted) numbers from those that are made up. Alongside the frequency of the first and second significant digits and their mean and standard deviation, a posited set of 'non-digit' input variables categorized as "information theoretic", "distance-based" and "goodness-of-fit" measures, help to minimize the critical classification errors that can lead to an audit failure. We come up with the optimal network structure for every instance corresponding to a 3 × 3 *Manipulation–Involvement matrix* that is drawn to depict the different combinations of the level of sophistication in data manipulation by the perpetrators of a financial fraud and also the extent of collusive involvement.

1. Introduction

Analytical review procedure (ARP) is one of a number of tools in an external auditor's toolbox to ascertain the credibility of an organization's financial reports. As per SAS 99 auditors are now expected to collect and consider a much more information than they did in the past in order to better assess fraud risks [36]. However fraud detection is still not universally perceived as being the primary responsibility of an external auditor. There exists a serious "expectation gap" between what various stakeholders perceive as auditor's primary responsibilities and what auditors are capable of doing or are equipped to do given time and budget constraints [45]. Of course; if a fraud has been committed chances are that some numbers would appear 'out of place' to an auditor, thus causing "red flags" to be raised and warranting a deeper investigation. ARPs are specialized *auditor decision support systems* intended to make the audit process more efficient by quickly identifying the 'out of place' numbers. ARPs have been attributed with the ability to detect more anomalies than they are typically given credit for if other detection procedures had failed [44].

However some degree of subjectivity is involved in traditional ARPs which rely heavily on the auditors' judgment. Our main research objective here is to try and build on earlier research on an ANN-based ARP that applies a particularly useful statistical law known as Benford's law and is less prone to subjective factors. Towards this objective, we firstly review relevant literature in Section 2. Secondly, in Section 3, we propose an ANN-based auditor decision support system to re-examine the efficacy of Benford's law in helping to correctly discriminate between data sets that are naturally occurring and others which aren't. Thirdly, in Section 4, we specify a proposed ANN-based auditor decision support system with an aim to improve on the classification results obtained by earlier researchers by identifying and testing input variables to minimize the number of critical errors. Finally, in Sections 5 and 6, we analyse our system output, compare it with the results of earlier researchers, draw conclusions and identify limitations.

2. Literature review

2.1. Artificial intelligence-based ARPs

Coakley and Brown [10] sought to improve a financial ratio analysis-based ARP by applying a neural network to select the most optimal ratios for the task. Fanning et al. [16] and Fanning and Cogger [15] firstly posited an ANN-based approach to detect managerial fraud and then applied it in a later paper using published financial data. Green and Choi [20] attempted something similar to Fanning and Cogger's paper a year later. Welch, Reeves and Welch [43] developed a classifier system for modeling auditor decision behavior in a fraud setting by applying a genetic algorithm approach. Feroz et al. [17] applied ANNs to study the efficacy of the "red flags" approach. Coakley and Brown [11] addressed some of the deeper modeling issues with

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ANN applications in accounting and finance. Lin et al. [30] further extended the ANN as a methodological tool in ARP by applying a fuzzy neural network model in the assessment of risk pertaining to fraudulent financial reporting. Kirkos et al. [25] tested the usefulness of decision trees, neural networks and Bayesian belief networks in identifying fraudulent financial reporting using ratios derived from financial statements to construct the input vectors.

However most previously published research works relied primarily on a single backbone AI technology rather than combining two or more different ones to obtain a more optimal classification engine for the specific task at hand. We on the other hand have attempted a hybrid approach by using a genetically optimized neural network, which ensures the most optimal neural network configuration in terms of both its architecture and input variable selection. Since the governing optimization problem is fairly complex and unstructured, Genetic Algorithm (GA) is likely the best approach to optimize the ANN and obtain best prediction results with test set data. A GA optimizer also makes the network building phase more efficient by rendering comparative analyses of alternative configurations superfluous, because by the principle of natural selection, only the most optimal configuration is expected to survive the evolutionary optimization process.

2.2. Benford's law in fraud detection

Frank Benford [2] collected numerical data on a wide variety of subjects in support of an observation that although the numbers were randomly selected, their digits followed a certain probability distribution that was not quite in accordance with human intuition (intuitively the digits should have an equal probability of occurrence). For the first significant digit, the formula for this probability distribution is as follows:

$$\mathrm{P}(D) = \log_e[(1 + 1\,/\,D)]\,/\,\log_e(10) \qquad (1)$$

In the formula D is any digit from 1 to 9. This formula can of course be generalized to cover second and subsequent significant digits. However the difference in probability of occurrence is most striking for the first significant digit. And beyond the second significant position, the occurrence probabilities tend to approximately converge to their intuitive equal values. Benford's law is analogous to another observation on rank-order occurrence that goes by the name of Zipf's law in honor of its discoverer [46]. Mathematically, Benford's law may actually be a special case of Zipf's Law [35]. The defining property of Benford's law is that it is observable only in *naturally occurring* numbers—not in numbers that have been artificially concocted. Thus, Benford's law may be regarded as a veritable *signature of Nature*—something that cannot be replicated manually [28]. This is the precise property that makes Benford's law extremely useful in detecting fraudulent financial data. When it comes to fraudulent manipulation of financial accounts, concocted numbers will not obey Benford's law thus increasing chances of detection via ARPs based on this law. Under a standard double-entry book-keeping system, figures that are made up to essentially "plug the gaps" caused by fraud can result in differences in the observed 1st and 2nd-digit frequencies from those predicted by Benford's law. Benford's law has very useful mathematical properties of base and scale invariance. Therefore an ARP that uses Benford's law is not affected by magnitude or 'history' of a transaction and therefore can be very effective in detecting "bleeding frauds" where small amounts are fraudulently siphoned over a period of time off via dubious transactions without alerting internal controls. Traditional review procedures while being able to identify frauds that involve a single high-value transaction may not however be effective in detecting such frauds. However, simply a failure to comply with Benford's law does not necessarily imply fraud—it merely provides some statistical evidence that the data may have been manipulated but does not reveal whether such manipulation is fraudulent or benign. So while Benford's law may be a useful tool, it has certain limitations which have been discussed by Kumar and Bhattacharya [28].

The background and development of Benford's law, as an effective tool in forensic accounting, has recently been comprehensively reviewed [14]. Significant academic research, albeit isolated, on the first digit law and its applications in financial fraud detection had been done previously. Carslaw [8] did an exploratory study concerning detection of anomalies in income numbers. Soon after, Thomas [41] used Benford's law to detect unusual patterns in reported earnings. But it was Mark Nigrini [31–33] who virtually pioneered application of Benford's law in forensic accounting by applying it to cases of tax evasion and other types of financial fraud. Dalal [12] reported a case where forensic accountants successfully used Benford's law in a real-life investigation to identify dubious transactions in one of the biggest financial frauds of recent times, which ultimately led to the collapse of a major international bank. Kumar and Bhattacharya [27] sought to design a computational algorithm based on Benford's law with the aim of making an audit sampling process more efficient. Watrin et al. [42] found under an experimental setting that subjects did not adapt to Benford's law while concocting numbers thereby lending credence to the robustness of this technique as an effective detection mechanism. S.-M. Huang et al. [22] proposed an innovative fraud detection mechanism based on Zipf's law. However the *only* paper to date published in a peer-reviewed, academic journal that combines Benford's law and ANNs as a review procedure is the one published in the Managerial Auditing Journal by Bruce Busta and Randy Weinberg [7], which largely motivated our current work.

2.3. The Manipulation–Involvement hypothesis

When a perpetrator of a fraud is highly resourceful, knowledgeable and organized, it is reasonable to assume that the manipulation of transaction records or books of accounts would have been done with a fair amount of sophistication so as to evade detection by any of the internal control systems in place. Moreover, when there is collusion it is also likely that a significant percentage of the detectable manipulations at the principal point of origin of the fraud would get suppressed as the perpetrators cooperate to 'cover up' their tracks at their respective ends effectively negating most if not all the 'check-and-balance' type internal control systems that are commonly used. Intuitively therefore, the complexity of a financial fraud (i.e., how well it is concealed so as to evade detection by reasonably alert internal control systems) would depend on both the level of sophistication in the manipulation of the financial records (the "Manipulation" variable) and the extent of involvement of multiple perpetrators (the "Involvement" variable). This is basically in line with the

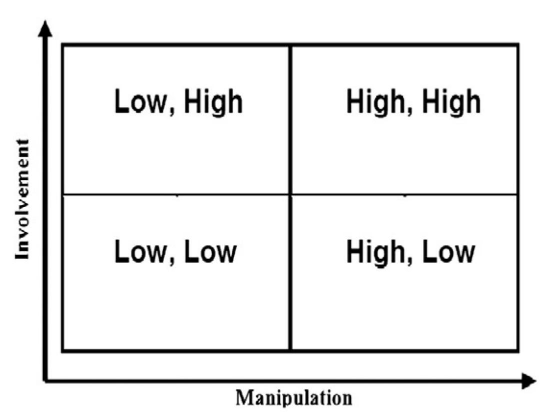

Fig. 1. A schema of the manipulation and involvement variables in collusive financial frauds.