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Introduction

A hybrid system is one that integrates two or more technologies. Integrating the two technologies is expected to apply the strengths and minimize the weaknesses of each technology. Often one or more intelligent technologies are integrated (Rabelo et al., 1990; Maren, 1990). The hybrid model developed here combines a statistical model with a rule-based expert system to assist in the audit opinion decision, and is implemented as the GC Advisor hybrid system. The system is programmed using an object-oriented system. Object-oriented models expand upon traditional dependencies between data elements by including *inheritance relations* between classes that are used to express specializations and generalizations of the concepts represented by classes (Korson and McGregor, 1990). The object-oriented method is combined with rule-based procedures in the GC Advisor in order to apply the system's logic. Incorporated into the logic of the auditor's going concern judgment is the process of generating as well as confirming or disconfirming hypotheses. A recent expert system designed by Benjamins and Jansweijer (1994) describes the process of symptom detection, hypothesis generation, and hypothesis discrimination. The feature included in their expert system for hypothesis discrimination allows for additional observations to be incorporated into the analysis before diagnosis is complete. The GC Advisor includes a similar feature.

The going concern uncertainty (GCU) opinion is issued by the auditor to a client company when that company is at risk of failure or exhibits other signs of distress that threaten its ability to continue as a going concern (Lenard et al., 1995). This decision facing the auditor involves the use of both quantitative and qualitative information. Statistical models have been used with varying degrees of success in predicting whether a firm should receive a going concern modification from publicly available information. Studies by Bell and Tabor (1991), Chen and Church (1992), and Lenard et al. (1995) use logit models or neural networks. These models represent the use of quantitative information to predict whether a firm should receive an audit report with a going concern modification, or whether a standard audit report, indicating a healthy firm, should be issued. In contrast to statistical models, expert systems provide the auditor with a

qualitative analysis of the going concern decision (Harris, 1989; Biggs and Selfridge, 1986).

The next step in evaluating the models which predict the going concern decision is to combine the quantitative and qualitative decision making models to produce a hybrid model. The focus of this paper is the development and testing of the hybrid model that predicts the going concern decision by combining the two models as described. This paper first presents a summary of prior research in hybrid models. Next, we summarize the design of the statistical model that performs the bankruptcy prediction. Input to the model is a training set of financial variables, as well as a binary response variable, that are used to indicate the financial health of a firm. The next section describes the development and testing of the expert system that uses rule-based logic to recommend whether or not a company should receive an audit report modified with a going concern uncertainty. Finally, the hybrid system is described that combines the first two models into a rule-based system that uses the statistical bankruptcy predictionmodel to assist in the determination of the audit opinion for a company. Once the statistical model and the expert system have been combined to form the hybrid model, we test the performance of the model using a series of test cases of bankrupt and nonbankrupt firms.

Previous Research in Hybrid Models

Rabelo et al. (1990) have combined neural networks and expert systems in the design of flexible manufacturing systems. They find, when using their model for scheduling, that the system has higher probability of success than traditional approaches. Maren (1990) describes a series of neural network hybrids that report improved results compared to traditional methods. Gevins and Morgan (1988) have developed systems of interacting neural networks to analyze multiple EEG signals recorded from the brain. Their network has replaced one of two human scorers who previously hand marked the data they collected. Rabelo and Avula (1991) use a hierarchical neural network system for intelligent control of a robotic arm.

Design of the Statistical Model

The M-estimator discriminant analysis has been proposed by Randles et al. (1978) and employed successfully by Booth et al. (1989), Hu et al. (1988), and Booth and Montasser (1985). The M-estimator method is a procedure which calculates the Mahalanobis distances and their associated weights. It is a robust procedure which diminishes the deleterious effect of outlying data observations without removing them from the data set (Booth et al., 1989). The procedure employed here consists of the M-estimator modification and a 0 cutoff for classification into the two groups of bankrupt or nonbankrupt firms.

Expert System Development

The expert system that is developed and described here is the Going Concern (GC) Advisor expert system. This system is extended to form the GC Advisor hybrid system.

The GC Advisor has been designed to summarize results of an audit that has already been performed. It serves as a mechanism to prompt the auditor to consider factors that affect the going concern decision. In this way, the system enables the auditor to form a hypothesis about the status of the firm. The main class, or domain, of the system represents the predominant feature of the auditing environment as the overall risk of the firm in terms of its financial health. The sub-classes in the hierarchy represent other specific features of the financial situation of the firm. These features have been divided into economic conditions, funding sources, future cash requirements, risk assessment and a report class. As the GC Advisor considers all the factors and begins to reach a conclusion, it presents a summary screen. This adds an extra step to the analysis and allows the user to implement hypothesis discrimination. At this point the user can reconsider or incorporate additional information into the analysis before a decision is recommended by the system. The report class is used for the system's conclusion display, which will recommend the type of audit report that should be filed.

Expert System Validation

The validation of expert systems is performed in order to assess whether interaction with the system leads to changes in the user's perception of the domain (Wensley, 1992). We have performed a validation with a group of 10 novice auditors. One limitation of the validation is the fact that the sample is quite small, so we cannot make generalizations regarding all expert systems from our data. Another limitation is that we have used the test subjects' written statements to evaluate the factors that they use to make the going concern uncertainty decision. The limitation of this process is similar to the limitation of verbal protocol analysis. Ericsson and Simon (1980) have concluded that when verbal protocol is used, some information may not be recalled. Because the verbal report is incomplete, some information used to make the decision may be unavailable. This does not invalidate the information that is present, but the fact remains that some details of the decision process may be missing (Biggs and Mock, 1983). Weber (1980) notes that experts tend to cluster wide-ranging incoming information into proper categories, a behavior that is lacking among novices. The GC Advisor expert system provides the novice with the ability to engage in this direct, goal-driven behavior. According to Abdolmohammadi and Wright (1987), it is important to recognize the difference between expert and novice behavior because it is "extremely valuable in designing decision aids and in developing staff training programs."

The Hybrid Model

Once we determined the best statistical model for predicting bankruptcy, it was incorporated into an Excel spreadsheet. The hybrid system accesses Excel using a feature supported by the Level-5 Object-Oriented Expert System called Dynamic Data Exchange (DDE). The equation from the statistical model has been entered into the Excel spreadsheet. The expert system requests the prediction value from the cell in the spreadsheet that contains the result.

Placement of the Statistical Model in the Expert System Logic

Statistical models that predict bankruptcy arrive at a conclusion using historical information. For the auditor to make an informed decision about a company's ability to continue as a going concern, he or she must evaluate how the company will obtain funding in order to operate for the 12 months into the future that is covered by the annual audit report. For this reason, a model which predicts bankruptcy is most useful during the evaluation of operating risk, when financial ratios are normally assessed. The statistical model therefore replaces the analysis of cash flow and other financial ratios that was previously performed by the rule-based analysis of the expert system in order to evaluate operating risk.

Model Accuracy

The GC Advisor hybrid system is the most accurate of the models in determining the type of audit report a firm should receive, based on the 1990 prediction sample. This accuracy compares favorably with that of other going concern prediction models. In comparison to other hybrid models, the GC Advisor reflects a similar result. Madey et al. (1993) describe a neural network that is embedded into a factory simulation for modeling continuous improvement policies. The authors report that the model, when running under the neural network's recommendations, produced simulated results over 12% better than when running without them. Hering et al. (1990) have found that by separately training and combining a system of networks, they could develop a system that makes distinctions that were difficult to encode into a single equivalently sized network.

Conclusion

The GC Advisor hybrid model described here has been proposed as the integration of an expert system and the *M*-estimator discriminant model and is designed to provide a more informed answer to the audit opinion decision. The results indicate that the hybrid model performs better than the other models. The GC Advisor hybrid model has been proposed as the integration of an expert system and a statistical model that is designed to provide a more informed answer to the audit opinion decision.

The GC Advisor hybrid system contributes to the literature in the development of decision support systems for several reasons. First, the system combines object-oriented programming with rule-based techniques. Second, the design using object-oriented methods allows the audit task environment to be divided into classes for more efficient programming and operation of the system. Third, the system employs an edit screen through the use of hyperregions and pushbuttons so that the user can enhance his or her judgment with the system's forward-chaining logic. The screen serves as a method to incorporate additional information or adjust previous responses as a form of hypothesis discrimination. The hybrid model provides a final contribution in terms of its combination of two methods (quantitative and qualitative) used as decision models.

Selected References

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Other references are available upon request.