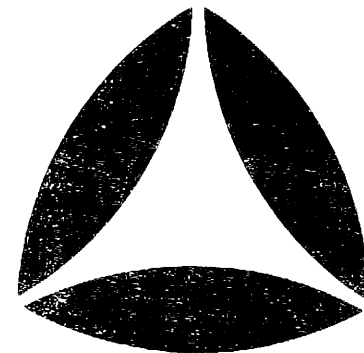


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AUDITOR'S ASSISTANT: A Knowledge Engineering Tool For Audit Decisions*

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1. Introduction

In recent years, there has been significant interest in developing expert systems for assistance in audit decisions [see e.g. Boritz and Wensley, 1988; Chandler, 1985; Hansen and Messier, 1986a, and 1986b; Leslie *et al.*, 1986]. It is believed that use of such systems will facilitate audit decisions and make audits more efficient and effective. This appears to be the reason that major accounting firms are committing increasingly greater resources to developing such systems [see e.g., Boritz and Brown, 1986; Kelly, 1987; Shpilberg and Graham, 1986].

Most of the expert systems being developed are rule-based. While such systems have many attractive features such as modularity of knowledge-base, ease of updating knowledge-base, etc., they are not well-suited for coherent reasoning under uncertainty. This is because in rule-based systems, the user has no control over the chain of inference whereas, coherent reasoning under uncertainty requires controlled firing of rules [Shafer, 1987]. Because of this difficulty, some developers of expert systems have avoided dealing with uncertainties altogether [Kelly *et al.*, 1986]. In domains where uncertain reasoning is unavoidable, heuristic approaches have been attempted with little success [Shortliffe and Buchanan, 1975; Duda *et al.*, 1976]. In recent years, considerable theoretical work has been done on the subject of coherent uncertain inference using Bayesian probabilities and belief-functions [see e.g., Pearl, 1986; Kong, 1986; Shenoy and Shafer, 1986; Mellouli, 1987; Shafer, Shenoy and Mellouli, 1987; Lauritzen and Spiegelhalter, 1988; Shafer and Shenoy, 1988]. The expert system described in this article represents one of the first practical applications of these new techniques.

The purpose of this paper is to describe an interactive tool called AUDITOR'S ASSISTANT (AA). The system, when fully developed, should

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enable its users (auditors) to construct a network of variables and evidence. The system will automatically aggregate all evidence that is entered and display the resulting beliefs in all variables in the network. The system will have the capability of using both the Bayesian and the belief-function formalisms for managing uncertainties. It will provide a graphic interface for constructing a network of variables and evidence and it will automatically revise beliefs in all variables as new pieces of evidence are entered.

This paper is divided into four sections. Section 2 provides a detailed discussion of AUDITOR'S ASSISTANT. Section 3 discusses an example demonstrating the process of constructing a network of variables and evidence and aggregation of evidence using the belief-function calculus. The final section summarizes the results. A brief introduction to the theory of belief-functions is given in Appendix A.

2. Auditor's Assistant

AUDITOR'S ASSISTANT is an interactive system for assisting auditors in making audit decisions. AA's theoretical foundation is based on coherent management of uncertain inference. With this system, an auditor can graphically create a network of variables and evidence, input judgments about the degree of support provided by a piece of evidence to the variable it is linked to, and evaluate the resulting total belief in all variables in the network. An auditor can also use the system to decide which procedure or test to perform next and also to decide when sufficient evidence has been obtained to issue an opinion.

In auditing the financial statements of a firm, there are two major conceptual tasks. First, an *argument* needs to be constructed. This is the process of organizing different pieces of evidence and the variables which they support. One formal result of this process is a network of variables and evidence. We shall refer to this network as a *design* [see Shafer and Cohen, 1987]. The process of constructing a design cannot be easily automated. It has to be done by a human expert, i.e., an experienced auditor. However, we can assist the auditor in this process by providing examples in the form of templates and by checking certain technical conditions, e.g., the Markov property [Shafer, Shenoy and Mellouli, 1987; Shafer and Shenoy, 1988], that have to be satisfied.

Second, once an argument is in place, evidence has to be collected, judgments about the degree of support provided by such evidence to variables have to be made, and these judgments have to be aggregated and evaluated for all variables in the tree. The collection of evidence and judgments of degree of support are tasks that have to be done by the auditor. However, the aggregation and evaluation of evidence can be automated.

The process of collecting evidence, making judgments, and aggregating judgments is iterative. Items of evidence are evaluated as they are collected, and this evaluation influences what evidence is collected next. The decisions about what evidence to seek next is one aspect of *control* [Cohen, 1987; Shafer and Cohen, 1987]. Again, this is not easy to automate. The experienced auditor makes these decisions. However, an interactive system should assist the auditor in these decisions in two ways. First, the system should automatically aggregate evidence as it is obtained and entered into the system, and the

system should display the net effect of all evidence on all variables in the network. Second, the system should allow a what-if analysis by allowing its user to enter a hypothetical piece of evidence and displaying its effect on all the variables. The user should then be able to retract this hypothetical evidence.

In general, as discussed in the professional standards [AICPA, 1987] and also in the academic literature [see, e.g., Graham 1985a-1985e], auditors gather three types of evidence. One type comes from reviews of the external and internal environments in which the business is operating. External environments include economic, social and political environments. Internal environments include management integrity, quality of management, structure of management, and the general business awareness of the management. A second type deals with the strength of internal accounting controls. A strong set of internal accounting controls may mean more reliable accounting data and, therefore, less need for substantive tests. The third type comes from performing substantive tests to determine directly whether account balances are fairly stated in accordance with generally accepted accounting principles. Such tests include analytical review procedures and direct tests of balances such as confirmations of receivables from customers.

There are several formalisms to aggregate uncertain evidence, including the Bayesian probability calculus [Pearl, 1986; Shenoy and Shafer, 1986; Lauritzen and Spiegelhalter, 1988; Shafer and Shenoy, 1988] and Shafer's theory of belief-functions [Shafer, 1976; Shenoy and Shafer, 1986; Kong, 1986; Shafer, Shenoy and Mellouli, 1987; Mellouli, 1987]. These calculi differ in their need for structure, inputs, flexibility and computational complexity. The Bayesian probability calculus demands structure in the form of conditional independence, and it demands numerous inputs in the form of priors and conditional probabilities, but it is relatively efficient computationally. The belief-function calculus offers more flexibility and demands less inputs, but it can be computationally more intensive than the Bayesian calculus.

AUDITOR'S ASSISTANT uses the belief-function calculus to represent and aggregate evidence. Shafer and Srivastava [1989] have demonstrated the importance and relevance of belief-functions for audit decisions based on the structure of audit evidence. Since the belief-function calculus reduces to the Bayesian calculus when all inputs demanded by the Bayesian calculus are available, AA can also work with probabilities.

Once a network is in place, the auditor conducts procedures and, on the basis of the results, he or she provides numerical degrees of support for the variable the evidence is linked to. Then, AA aggregates the evidence and maintains a display of the degrees of support provided by all evidence collected so far to all variables in the network.

As it exists today, AA allows an auditor to construct only a tree of variables and evidence. No loops are allowed. However, AA is currently being updated to include arbitrary networks. The user creates the tree visually and interactively using a mouse as an input device. The nodes of the tree represent variables and the links between nodes represent relations between variables. The user has many options for manipulating the tree on the screen: moving a node by dragging it, collapsing a sub-tree into a node, etc.

3. An Example

In this section we will describe the use of AA in a simple audit engagement.¹

Suppose ABC Hardware Co. is a small wholesale distributor of hardware located in the Midwest. Most of ABC's customers are retail hardware stores. Srifer & Co. has been asked to perform an annual audit of ABC's financial statements.

3.1. Constructing a Network of Variables and Evidence

Srifer & Co. has audited ABC Hardware's financial statements for the last four years. After reviewing the previous years' working papers and understanding the client's business environment, the audit team (consisting of a senior, manager and partner) constructs a network of variables and evidence related to accounts receivables (AR) and allowance for bad debts (ABD). For simplicity of exposition, we assume that the audit team has decided not to depend on the internal accounting controls in the sales and collection cycle. Thus, the audit team will depend only on the environmental factors, analytical review results, and some direct tests of balances. This network is shown in Figure 1.

The rounded rectangular nodes represent *variables* that are of interest to the auditor. For example, the main variable in Figure 1 is whether net accounts receivable is fairly stated. Associated with each variable is a collection of mutually exclusive and collectively exhaustive *values*. For example, the values associated with the net accounts receivable variable are nar (denoting that net accounts receivable is fairly stated) and ~nar (denoting that net accounts receivable is not fairly stated). All variables in Figure 1 are binary-valued. A brief description of each variable is indicated inside the node.

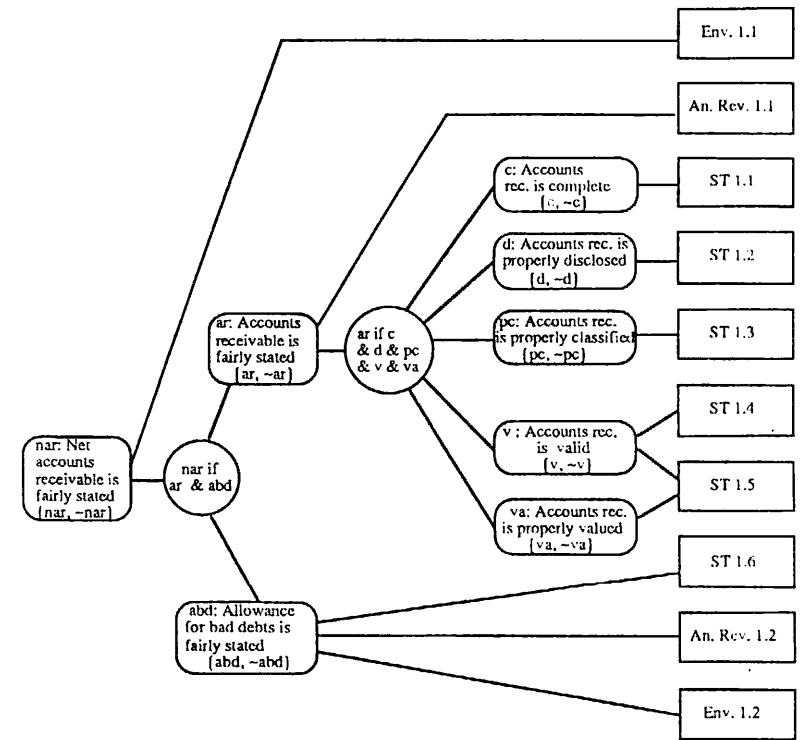
The circular nodes represent *relations* between the variables they are linked to. For example, net accounts receivable is fairly stated if and only if both accounts receivable and allowance for bad debts are fairly stated. Also, accounts receivable is fairly stated if and only the following objectives have been met: *completeness, ownership, adequate disclosure, proper classification, validity* and *valuation* (see, e.g., Arens and Loebbecke [1988], for further discussion of these objectives). Formally, a relation is modeled as a belief-function. For example, the relation between net accounts receivable, accounts receivable and allowance for bad debts can be represented in terms of a basic probability assignment function m as follows (see Appendix A for a definition of m):

$$m(\{\text{nar}, \text{ar}, \text{abd}\}, (\sim \text{nar}, \text{ar}, \sim \text{abd}), (\sim \text{nar}, \sim \text{ar}, \text{abd}), (\sim \text{nar}, \sim \text{ar}, \sim \text{abd})) = 1.$$

The rectangular nodes represent *evidence*. A description of the procedures and tests leading to the evidence shown in Figure 1 is given in Table 1. The links between evidence nodes and variable nodes indicate that the evidence provides some support for the variables it is linked to. For example, in Figure 1

¹ The main purpose of this example is to illustrate the use of AA in planning and evaluation decisions. The numerical inputs used in the example are purely for illustration purposes.

Figure 1. A network of variables and evidence for ABC Hardware.



evidence Env. 1.1 provides support directly to the net accounts receivable variable.

Formally, each piece of evidence is modeled as a belief-function on the set of possible values of the variables it is linked to. For example, if the outcome of the Env. 1.1 procedure results in a 60% degree of support for nar, then this piece of evidence is represented in the system as follows:

$$m(\{\text{nar}\}) = 0.60, m(\{\text{nar}, \sim \text{nar}\}) = 0.40.$$

Functions of this type (where a certain degree is committed to one value of a variable and the rest is uncommitted) are called *simple support functions*. We expect most of the evidence to be of this type. Thus, in order to make a judgment about a piece of evidence, an auditor needs to decide whether the evidence supports the affirmative or negative value of a variable, and the degree (a number between 0 and 1) to which it does so.

At the outset of the engagement (before any tests or procedures have been performed), a network of variables and evidence, such as the one shown in Figure 1, serves as a plan for performing the audit. Before a procedure is

TABLE 1. Description of procedures and tests leading to evidence shown in Figure 1.

An. Rev. 1.1	Review AR journal for unusual items and compare individual customer balances over a stated amount with previous years.
An. Rev. 1.2	a. Compare allowance for bad debt as a percentage of accounts receivable with previous years. b. Compare number of days accounts receivable outstanding with previous years. c. Compare bad debt expense as a percentage of gross sales with previous years.
Env. 1.1	Review the competence and trustworthiness of the accounting personnel working in sales transactions.
Env. 1.2	Review management's credit policy.
ST 1.1	Trace a sample of accounts from the subsidiary ledger to the aged trial balance.
ST 1.2	Review the minutes of the board of directors' meetings for any pledged or factored accounts receivable. Also inquire of management whether any receivables are pledged or factored.
ST 1.3	Review the receivables listed on the aged trial balance for notes and related party receivables.
ST 1.4	Trace a sample of accounts from the trial balance to the related subsidiary ledger.
ST 1.5	Confirm accounts receivables from customers.
ST 1.6	Discuss with credit manager the likelihood of collecting older accounts over 120 days and evaluate whether the receivables are collectible.

performed, it is represented in the system as a *vacuous* belief-function (see Appendix A for the definition of a *vacuous* belief-function). Propagating all these belief-functions results in zero belief for each value for all variables in the network. In other words, before collecting any evidence, the auditor is completely ignorant about whether the financial statements are fairly presented or contain a material error. However, once a test is performed, the auditor makes a numerical judgment about the degree of support provided by the test to the variable the evidence is linked to in the network. After this is entered into the system, the system propagates the evidence to all variables in the network and the revised beliefs for all variables are then displayed.

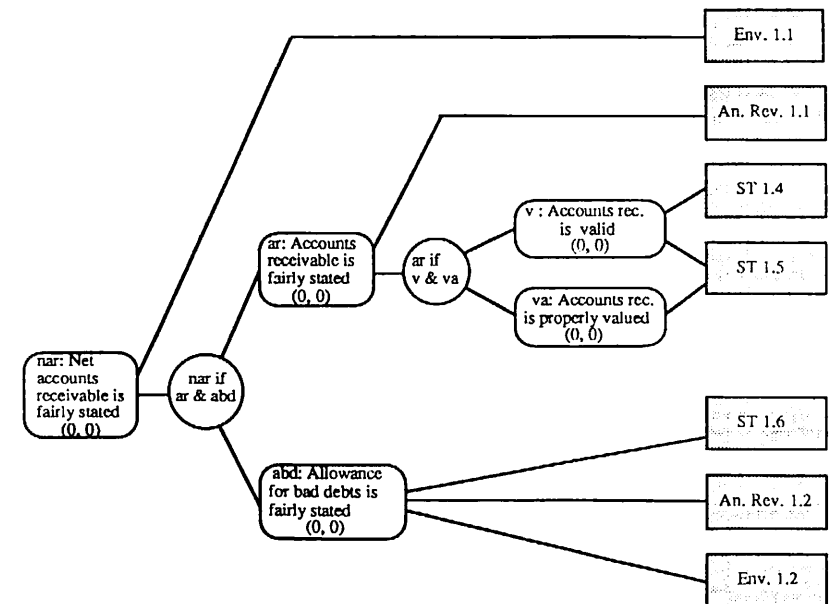
At any stage of the audit, the auditor has to decide which procedures he or she is going to perform next. Of course, at any stage of the audit, depending on the results of the tests already conducted, an auditor may decide that certain procedures are unnecessary. On the other hand, an auditor may need to change his or her plan to include more tests because the tests planned for do not provide the necessary evidence to issue an opinion.

3.2. Planning and Aggregation of Evidence

To illustrate the planning of the audit and the aggregation of evidence, we will further simplify the example. Assume that the audit team has concluded that the objectives of *completeness*, *ownership*, *adequate disclosure*, and *proper classification* have been met without any reservations. The objectives yet to be verified are *validity* and *valuation* for AR. The network relevant to this situation is shown in Figure 2. The rectangular nodes are shown with a dotted fill in Figure 2 to indicate that none of these procedures has been performed yet. Since no procedures have been performed yet, no support is available to any of the values of the variables as shown in Figure 2. For each variable in the network, there are two numbers shown inside the rectangular box at the bottom. The first of these two numbers indicates the total belief for the affirmative value of the variable. For example, for the NAR variable, $Bel(\{nar\}) = 0$ in Figure 2. The second number indicates the total belief for the negative value of the variable. For example, for the NAR variable, $Bel(\{\sim nar\}) = 0$ in Figure 2.

We will consider two different scenarios and the resulting evaluations about the fairness of NAR.

Figure 2. The simplified network of Figure 1.

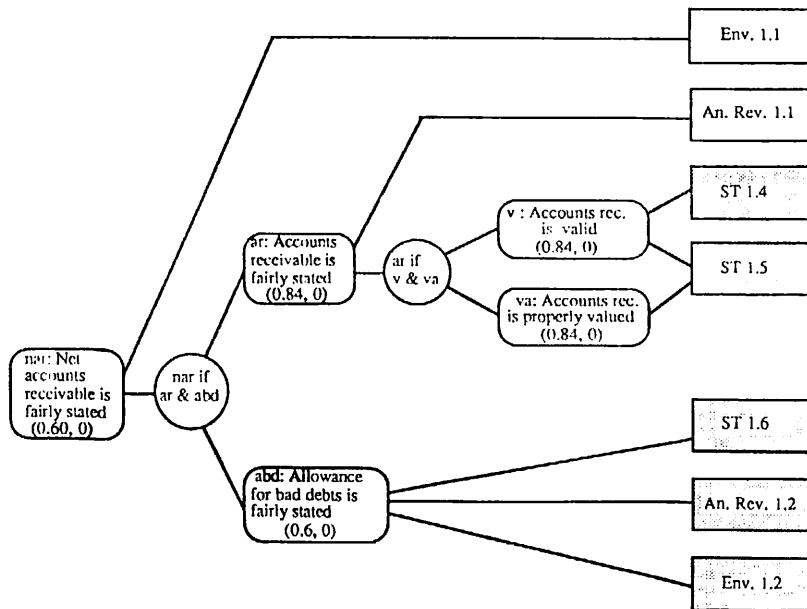


3.2.1. Scenario One

Suppose that the audit team finds the management and accounting personnel to be competent and trustworthy (Env. 1.1). The audit team decides that this evidence supports nar to degree 0.60. Also, the results of the analytical review procedures (An. Rev. 1.1) show no unusual items and no apparent problems in AR balance. The team makes a judgment that this supports 'ar' to degree 0.60. These judgments are propagated through the network resulting in the beliefs shown in Figure 3. Notice that there is now an overall support of 0.60 for the assertion that NAR is fairly presented and no support for the assertion that NAR is materially misstated (i.e., $Bel(\{nar\})=0.60$, $Bel(\{\sim nar\})=0$). Although there is no support for the assertion that NAR is materially misstated, there is a maximum 40% risk based on the two pieces of evidence that NAR could be materially misstated (i.e., $Pl(\{\sim nar\})=0.40$ where Pl is a plausibility function related to the belief-function Bel by the relation $Pl(\{\sim nar\})=1 - Bel(\{nar\})$).

Let us assume that the audit team plans to conduct the audit so that they obtain at least 90% overall support for nar, i.e., targeted $Bel(\{nar\})$ is 0.90. Note that the evidence from An. Rev. 1.1 provides no support yet to nar since no support for abd has yet been obtained from procedures, ST 1.6, An. Rev. 1.2, and Env. 1.2 (remember that NAR is fairly stated only when AR and ABD

Figure 3. The network of variables after performing Env. 1.1 and An. Rev. 1.1 in Scenario One.

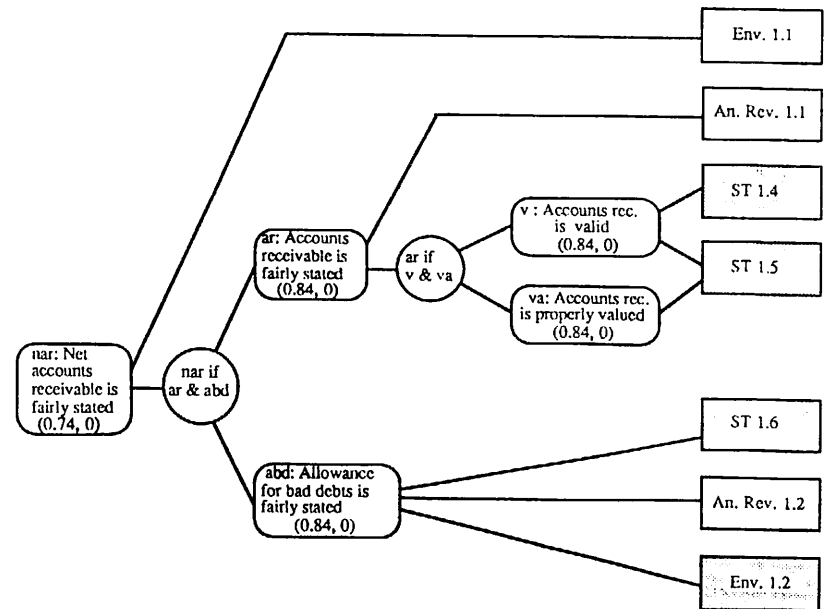


are fairly stated). It should be noted that ar and the two objectives of ar (validity and valuation) in Figure 4 have 84% support from Env. 1.1 and An. Rev. 1.1. The 0.60 support for nar is entirely due to Env. 1.1. Therefore, the team decides to perform analytical review procedures for allowance for bad debts (An. Rev. 1.2) next.

Suppose they find that the allowance is reasonable given the accounts receivable balance. Also, certain ratio analyses suggest that ABD is fairly presented. The team makes a conservative judgment that a 60% degree of support is obtained from this evidence for abd. The resulting network is shown in Figure 4. Thus, propagating the three judgments through the network results in an overall support for nar of 0.74 and no support for $\sim nar$ (i.e., $Bel(\{nar\})=0.74$, $Bel(\{\sim nar\})=0$).

Next, since not enough support is available yet for nar, the team decides to perform substantive test procedures for validity and valuation of AR. (Of course, the team recognizes that certain substantive test procedures are required by the AICPA. For example, confirmations of AR from the customers is a requirement [AICPA, 1987, AU331]). The extent of testing would depend on the level of support desired by the team. Let us assume that they plan on achieving 80% support for validity of AR by tracing a sample of accounts from the aged trial balance to the related subsidiary ledger. The senior performs the

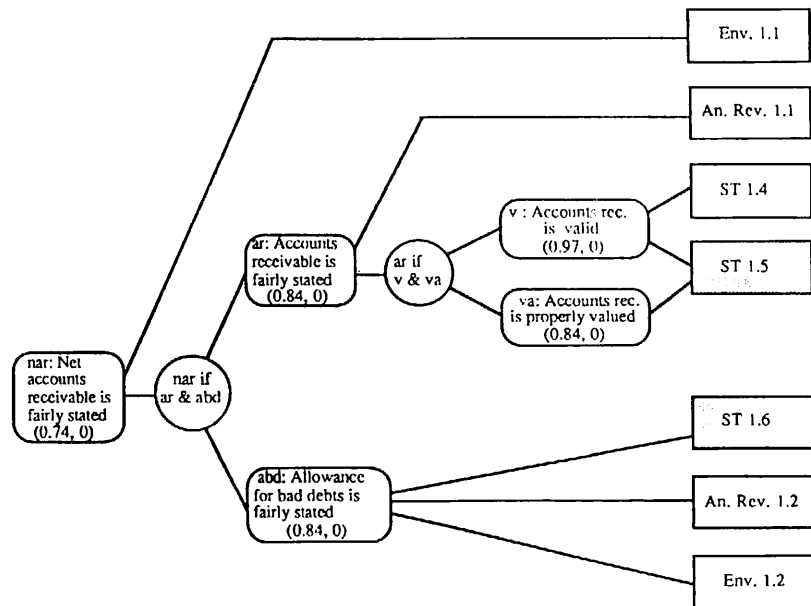
Figure 4. The network after performing Env. 1.1, An. Rev. 1.1 and An. Rev. 1.2 in Scenario One.



test and finds no exceptions. The team makes a judgment that an 80% degree of support is obtained by the evidence for the validity objective. This evidence is entered into the system and the resulting network is shown in Figure 5. The overall support for nar is still 0.74. The reason for no change in the overall support for nar is that the evidence from ST 1.4 supports only the validity objective. There is no direct support yet for the valuation objective. Since both objectives have to be met for AR to be fairly presented, ST 1.4 provides no support by itself to the fair presentation of AR. However, the level of support shown in Figure 5 represents the overall support when all the items of evidence have been aggregated.

As discussed earlier, AUDITOR'S ASSISTANT would have the capability of performing a what-if analysis for deciding the nature, timing, and extent of tests. In principle, the auditor can assume a certain level of support that he or she plans to obtain from a test procedure and see its impact on the overall support for the main assertion of interest. Of course, the decision about what test to perform next, and the extent of the test, depends on the auditor. The cost of performing a test has to be balanced with the level of support desired. Usually, analytical review procedures do not provide a high level of support unless the test involves statistical analyses. Similarly, making inquiries of the

Figure 5. The network after performing Env. 1.1, An. Rev. 1.1, An. Rev. 1.2 and ST 1.4 in Scenario One.

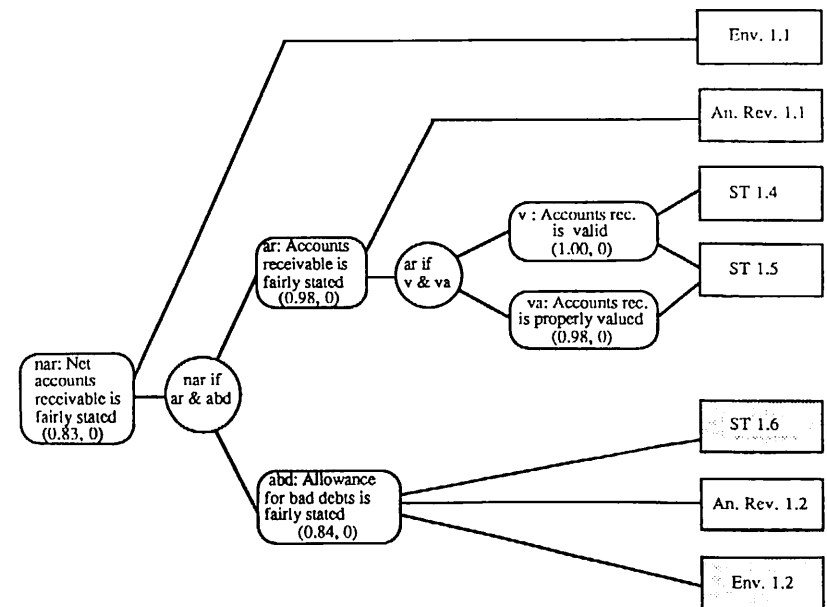


client provides a lower level of support. However, confirmation from third parties is considered to be reliable and it provides a higher level of support.

Now suppose that the team decides to send a sample of positive confirmations to the client's customers in order to achieve a 90% degree of support for the validity of AR. The confirmation test also provides support for the valuation objective to a great extent because the customer usually checks the account balance for accuracy. The audit staff analyzes the returned confirmations and finds no exceptions. The team, having reviewed the staff's work, makes a judgment that the confirmation test provides a 90% degree of support for the validity objective and an 85% degree of support for the valuation objective. For simplicity of exposition, we will assume that the above two judgments are independent. The resulting beliefs of all variables are shown in Figure 6. The overall support for nar is now 0.83 and there is still no support for $\sim nar$ (i.e., $Bel(\{nar\}) = 0.83$, $Bel(\{\sim nar\}) = 0$).

Since the overall support for nar is still below the target level of 0.90, the team plans to perform some further tests. Since the support for ar is already quite high ($Bel(\{ar\}) = 0.98$), they conclude that there is no need for further evidence that supports ar. However, support for abd is still low ($Bel(\{abd\}) = 0.84$). Thus, they decide to meet with the credit manager to discuss whether the firm has any collectibility problems with their accounts (ST

Figure 6. The network after performing Env. 1.1, An. Rev. 1.1, An. Rev. 1.2, ST 1.4, and ST 1.5 in Scenario One.



1.6). They find that there is no account that is more than 120 days overdue. Furthermore, all accounts seem to be quite good. The team makes a judgment that this evidence supports *abd* to degree 0.60. The resulting beliefs for the variables are shown in Figure 7. The overall support for *nar* is now 0.92 and there is no evidence to support $\sim nar$ (i.e., $Bel(\{nar\})=0.92$, $Bel(\{\sim nar\})=0$).

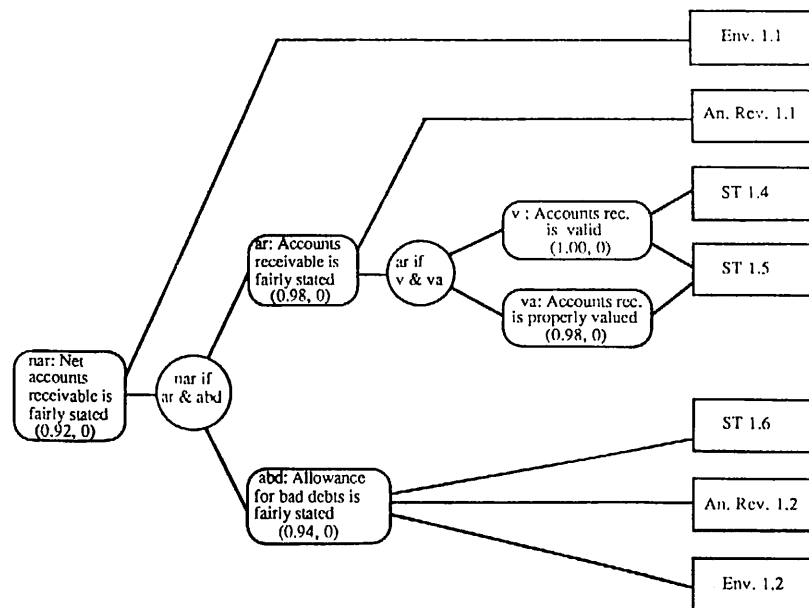
At this stage, the audit team decides to conclude the audit since they have sufficient evidence to issue an opinion about the fairness of NAR. The audit team also knows that given the evidence, the maximum risk that NAR is materially misstated is only 8%.

Although the audit team had initially planned to review ABC's credit policy (Env. 1.2), they do not perform this test since, on the basis of tests already conducted, they have a sufficiently high belief that NAR is fairly stated. Without a formal analysis of the type shown above, perhaps an audit team may end up doing more tests than necessary. AUDITOR'S ASSISTANT, when fully developed, should provide assistance to auditors in deciding when sufficient evidence has been collected to issue an opinion.

3.2.2. Scenario Two

In this case, assume that the results of Env. 1.1, An. Rev. 1.1, ST 1.4, and

Figure 7. The network after performing Env. 1.1, An. Rev. 1.1, An. Rev. 1.2, ST 1.4, ST 1.5, and ST 1.6 in Scenario One.



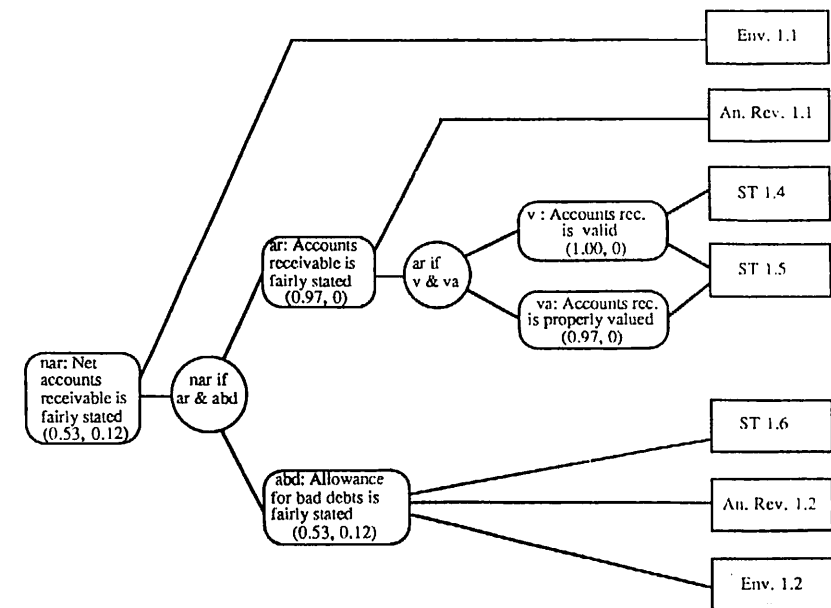
ST 1.5 are the same as in Scenario One. The results of An. Rev. 1.2 and ST 1.6 are different from the ones described above.

Suppose that the analytical review procedure An. Rev. 1.2 performed by the senior has revealed that the allowance for bad debts may be understated in relation to this year's accounts receivable balance. Also the AR balance has increased significantly compared to the credit sales, implying that a more liberal credit policy has been adopted this year, compared to the past. Furthermore, the collection of receivables is slow. Based on this evidence, the audit team makes a judgment that ABD is understated to degree 0.25. The aggregate beliefs in all variables are now shown in Figure 8. The overall beliefs in *nar* and $\sim nar$ are 0.53 and 0.12, respectively. The maximum risk of NAR being materially misstated is 0.47 (i.e., $Pl(\{\sim nar\})=1 - Bel(\{nar\})=0.47$).

The audit team now decides to review the client's credit policy (Env. 1.2). The senior performs the review and finds that this year, the client has been quite liberal in granting credit. He attributes the increase in AR balance this year to the firm's liberal credit policy. The team makes a judgment that the evidence supports $\sim abd$ to degree 0.40.

The senior also meets with the credit manager to discuss the firm's credit policy (ST 1.6). The credit manager agrees with the senior's assessment that allowance for bad debts may be understated. Based on this evidence, the audit

Figure 8. The network after performing Env. 1.1, An. Rev. 1.1, ST 1.4, ST 1.5, and An. Rev. 1.2 in Scenario Two.

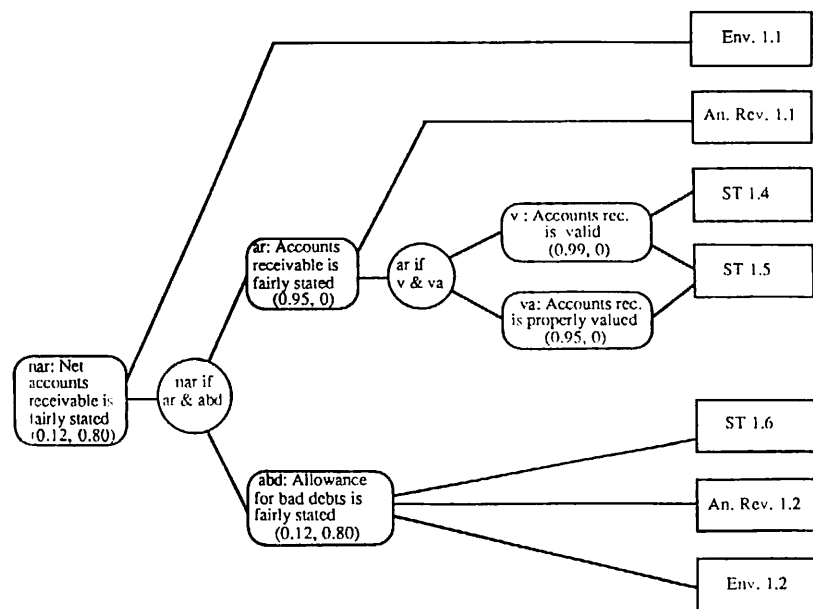


team makes a judgment that supports ~abd to degree 0.80. This judgment, when combined with the previous findings, yields an overall support of 0.80 for ~abd (see Figure 9). Therefore, the audit team decides at this point to propose an adjustment for ABD. No adjustment need be proposed for AR since the overall support for ar is 0.95, which is above their target level.

4. Summary

AUDITOR'S ASSISTANT is not a rule-based system. The knowledge-base of AA is a network of variables and evidence. Since each auditing engagement is unique, a network of variables and evidence has to be constructed by the user. There are several ways in which the system assists the user with this task. First, the graphics user interface of AA is designed to make the task of constructing a network as easy and intuitive as possible. Second, the user does not have to start from scratch. Instead, (s)he can start with a template and modify it to fit the engagement at hand. The system automatically handles technical aspects of network construction such as ensuring that the network satisfies the Markov property. Also, the system (when fully developed) should automatically reduce a non-tree network to a tree by clustering variables and using the resulting clustered tree to propagate the evidence. At this time, the

Figure 9. The network after performing Env. 1.1, An. Rev. 1.1, ST 1.4, ST 1.5, An. Rev. 1.2, Env. 1.2 and ST 1.6 in Scenario Two.



system is only capable of propagating belief-functions in networks that are already trees.

The user can use the network of variables and evidence as a planning device. At each stage, AA will display the beliefs for each variable in the network as a function of the evidence that has been collected and entered into the system. At each stage, the user needs to decide what test or procedure to perform next. AA can assist in this decision by performing a what-if analysis and indicating the degree of belief provided to the main variable of interest as a function of the test results. The auditor can then choose between different tests and sample sizes based on cost of test and increase in degree of belief for the main variable of interest.

When there is sufficient belief for the main variable of interest, the auditor can issue an appropriate opinion.

In summary, it is useful to think of AUDITOR'S ASSISTANT as a *knowledge engineering* tool instead of as an expert system. Coherent reasoning under uncertainty requires construction of an argument. Once an argument is in place, aggregation of evidence is easily automated.

References

- American Institute of Certified Public Accountants, *AICPA Professional Standards*, Vol. A (Commerce Clearing House, 1987).
- Arens, A. A., and J. K. Loebbecke, *Auditing: An Integrated Approach*, 4th Edition (Prentice Hall, 1988).
- Boritz, J. E., and D. A. Brown, "The Expert-Ease at Expert Systems," *CA MAGAZINE* (August 1986), pp. 50-57.
- Boritz, J. E., and A. K. P. Wensley, "Structuring the Assessment of Audit Evidence—An Expert Systems Approach," presented at the 1987 University of Waterloo Auditing Symposium, also to appear in the *Auditing: A Journal of Practice and Theory* (1989).
- Chandler, J. S., "Expert Systems in Auditing: The State of the Art," *The Auditor's Report*, Vol. 8, No. 3 (Summer 1985), pp. 1-4.
- Cohen, P. R., "The Control of Reasoning under Uncertainty: A Discussion of Some Programs," *The Knowledge Engineering Review*, Vol. 2 (March 1987), pp. 5-25.
- Duda, R. O., P. E. Hart, and N. J. Nilsson, "Subjective Bayesian Methods for Rule-Based Inference Systems," *AFIPS Conference Proceedings*, Vol. 45 (1976), pp. 1075-1082.
- Graham, L. E., "Audit risk—Part I," *The CPA Journal* (August 1985a), pp. 12-21.
- Graham, L. E., "Audit risk—Part II," *The CPA Journal* (September 1985b), pp. 34-40.
- Graham, L. E., "Audit risk—Part III," *The CPA Journal* (October 1985c), pp. 36-43.
- Graham, L. E., "Audit risk—Part IV," *The CPA Journal* (November 1985d), pp. 38-45.
- Graham, L. E., "Audit risk—Part V," *The CPA Journal* (December 1985e), pp. 26-33.
- Hansen, J. V., and W. F. Messier, "Expert Systems for Decision Support in EDP Auditing," *International Journal of Computer and Information Sciences*, Vol. 11, No. 5 (1982), pp. 357-379.
- Hansen, J. V., and W. F. Messier, "A Preliminary Investigation of EDP-XPERT," *Auditing: A Journal of Practice and Theory*, Vol. 6, No. 1 (1986a), pp. 109-123.
- Hansen, J. V., and W. F. Messier, "A Knowledge Based Expert System for Auditing Advanced Computer Systems," *European Journal of Operations Research* (September 1986b), pp. 371-379.
- Kelly, P. K., "Modeling the Audit Planning Process," *Expert Systems Review For Business and Accounting* (September-October 1987), pp. 3-8.
- Kelly, K. P., G. S. Ribar, and J. J. Willingham, "Interim Report on the Development of an Expert System for the Auditor's Loan Loss Evaluation," in *Proceedings of the 1986 Touche Ross/University of Kansas Symposium on Auditing Problems* (1986), pp. 167-188.
- Kong, A., "Multivariate Belief Functions and Graphical Models," Doctoral dissertation, Department of Statistics, Harvard University (1986).
- Lauritzen, S. L., and D. J. Spiegelhalter, "Local Computations with Probabilities on Graphical

Structures and Their Application to Expert Systems," *Journal of the Royal Statistical Society*, Vol. 50(B) (1988), pp. 157-224.

Leslie D. A., S. J. Aldersley, D. J. Cockburn, and C. J. Reiter, "An Assertion Based Approach to Auditing," in *Proceedings of the 1986 Touche Ross/University of Kansas Symposium on Auditing Problems* (1986), pp. 31-68.

Mellouli, K., "On the Propagation of Beliefs in Networks Using the Dempster-Shafer Theory of Evidence," Doctoral dissertation, School of Business, University of Kansas (1987).

Pearl, J., "Fusion, Propagation, and Structuring in Belief Networks," *Artificial Intelligence*, Vol. 29 (1986), pp. 241-288.

Shafer, G., *A Mathematical Theory of Evidence*, Princeton University Press (1976).

Shafer, G., "Probability Judgment in Artificial Intelligence and Expert Systems," *Statistical Science*, Vol. 2, No. 3 (1987), pp. 3-44.

Shafer, G., and P. Cohen, "Management of Uncertainty in Expert Systems," Tutorial offered at the *Sixth National Conference on Artificial Intelligence*, AAAI-87, Seattle, WA (1987).

Shafer, G., P. P. Shenoy, and K. Mellouli, "Propagating Belief Functions in Qualitative Markov Trees," *International Journal of Approximate Reasoning*, Vol. 1 (1987), pp. 349-400.

Shafer, G., and P. P. Shenoy, "Local Computation in Hypertrees," School of Business Working Paper No. 201, University of Kansas (1988).

Shafer, G., and R. P. Srivastava, "The Bayesian and Belief Function Formalisms I: A General Perspective for Auditing," presented at the 1987 University of Waterloo Auditing Symposium, also to appear in *Auditing: A Journal of Practice and Theory* (1989).

Shenoy, P. P., and G. Shafer, "Propagating Belief Functions with Local Propagation," *IEEE Expert*, Vol. 1 (1986), pp. 43-52.

Shpilberg, D., and L. Graham, "Developing ExpertTAXSM: An Expert System for Corporate Tax Accrual and Planning," *Auditing: A Journal of Practice and Theory* (Fall 1986), pp. 75-94.

Shortliffe, E. H., and B. G. Buchanan, "A Model of Inexact Reasoning in Medicine," *Mathematical Biosciences*, Vol. 23 (1975), pp. 351-379.

Appendix A

A Primer on The Theory of Belief Functions

Here we shall present the basics of the theory of belief-functions. See Shafer [1976] for details.

Let X denote a variable with possible values x_1, \dots, x_n . We shall refer to the set of all possible values of a variable (exactly one of which is true) as a *frame of discernment*. A *basic probability assignment* (bpa) function on a frame Θ is a function $m:2^\Theta \rightarrow [0,1]$ such that

$$m(A) \geq 0 \text{ for all } A \in 2^\Theta, m(\phi) = 0, \text{ and } \sum \{m(A) | A \in 2^\Theta\} = 1$$

Intuitively, $m(A)$ represents the degree of belief assigned exactly to A (the proposition that the true value of X is in the set A). A basic probability assignment function corresponds to a probability mass function in Bayesian probability theory. Whereas a probability mass function is restricted to assigning probability masses only to singleton values of variables, a bpa function is allowed to assign masses to sets of values without assigning any mass to the individual values contained in the sets. For example, if we have absolutely no knowledge about the true value of a variable, we can represent this situation by a bpa function as follows:

$$m(\Theta) = 1, m(A) = 0 \text{ for all other } A \in 2^\Theta.$$

Such a function is called a *vacuous* bpa function. Note that in Bayesian probability theory, the only way to express total ignorance is to assign a mass of $1/n$ to each value where n is the total number of possible values. Thus, in Bayesian probability theory we are unable to distinguish between equally likely

values and total ignorance. The theory of belief-functions offers a richer semantics.

Associated with a bpa function are two related functions called belief and plausibility. A *belief-function* is a function $\text{Bel}:2^\Theta \rightarrow [0,1]$ such that

$$\text{Bel}(A) = \sum \{m(B) | B \subseteq A\}.$$

Whereas $m(A)$ represented the belief assigned exactly to A , $\text{Bel}(A)$ represents the total belief assigned to A . Note that $\text{Bel}(\phi) = 0$ and $\text{Bel}(\Theta) = 1$ for any bpa function. For the vacuous bpa function m , the corresponding belief-function Bel is given by

$$\text{Bel}(\Theta) = 1, \text{ and } \text{Bel}(A) = 0 \text{ for all other } A \in 2^\Theta.$$

A *plausibility function* is a function $\text{Pl}:2^\Theta \rightarrow [0,1]$ such that

$$\text{Pl}(A) = \sum \{m(B) | B \cap A \neq \phi\}$$

$\text{Pl}(A)$ represents the total degree of belief that could be assigned to A . Note that $\text{Pl}(A) = 1 - \text{Bel}(\sim A)$ where $\sim A$ represents the complement of A in Θ , i.e., $\sim A = \Theta - A$. Also note that $\text{Pl}(A) \geq \text{Bel}(A)$. For the vacuous bpa function, the corresponding plausibility function is

$$\text{Pl}(\phi) = 0, \text{ and } \text{Pl}(A) = 1 \text{ for all } A \in \Theta.$$

If a bpa function m is also a probability mass function (i.e., all the probability masses are assigned only to singleton subsets), then $\text{Bel}(A) = \text{Pl}(A) = \sum \{m(\{x_i\}) | x_i \in A\}$ = probability of proposition A .

If m_1 and m_2 are bpa functions representing two independent pieces of evidence, then we can combine them using *Dempster's rule of combination* and obtain a new bpa function, denoted by $m_1 \oplus m_2$, representing the aggregated evidence as follows:

$m_1 \oplus m_2(A) = K^{-1} \sum \{m_1(B_1)m_2(B_2) | B_1 \cap B_2 = A\}$ if $A \neq \phi$, and $m_1 \oplus m_2(\phi) = 0$ where $K = 1 - \sum \{m_1(B_1)m_2(B_2) | B_1 \cap B_2 = \phi\}$. The above definition assumes that $K \neq 0$. If $K = 0$, then the two pieces of evidence contradict each other completely, and it is not possible to combine such evidence.

Let us illustrate Dempster's rule of combination by means of two examples.

Example 1

Suppose that the variable under consideration is the validity of accounts receivable with frame $\{v, \sim v\}$. The results of substantive test 1.4 lead to the bpa function m_1 as follows:

$$m_1(\{v\}) = .8, m_1(\{v, \sim v\}) = .2$$

Furthermore, results of substantive test 1.5 lead to the bpa function m_2 as follows:

$$m_2(\{v\}) = 0.9, m_2(\{v, \sim v\}) = .1$$

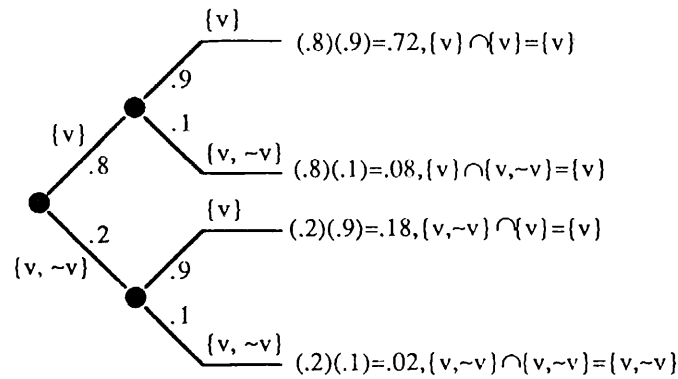
Combining m_1 and m_2 by Dempster's rule leads to the bpa function $m_1 \oplus m_2$ as follows:

$$m_1 \oplus m_2(\{v\}) = .72 + .08 + .18 = .98,$$

$$m_1 \oplus m_2(\{v, \sim v\}) = .02.$$

The details of Dempster's rule are shown in Figure 10. In this example, there is no conflict between the two pieces of evidence, i.e., $K = 1$.

Figure 10. Dempster's rule for Example 1



Example 2

Suppose that the variable under consideration is the fairness of allowance for bad debts with frame $\{abd, \sim abd\}$. The results of an analytical review test lead to a bpa function m_1 as follows.

$$m_1(\{abd\}) = 0.8, m_1(\{abd, \sim abd\}) = 0.2$$

However, an environmental review uncovers the fact that one of the client's major customers has filed for Chapter 11 and may not be in a position to pay its bills. Let us represent this evidence as follows:

$$m_2(\{\sim abd\}) = 0.1, m_2(\{abd, \sim abd\}) = 0.9$$

Combining these two pieces of evidence leads to the aggregated bpa function:

$$m_1 \oplus m_2(\{abd\}) = .72/0.92 = .78$$

$$m_1 \oplus m_2(\{\sim abd\}) = .02/0.92 = .02$$

$$m_1 \oplus m_2(\{abd, \sim abd\}) = .18/0.92 = .20$$

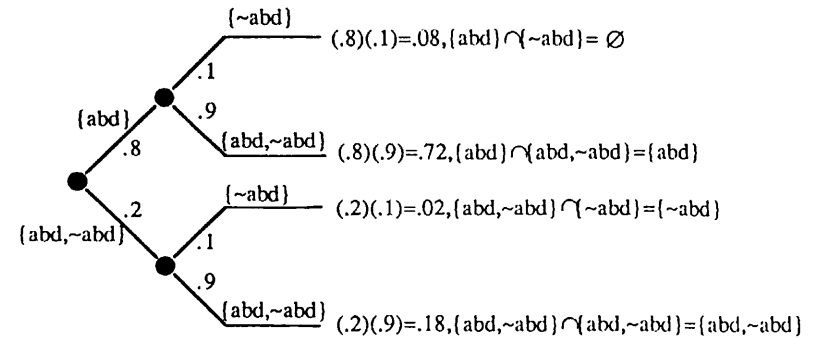
The details of Dempster's rule are shown in Figure 11. Note that in this case the evidence is conflicting ($K = 1 - .08 = 0.92$) and so we end up renormalizing the bpa function so that the values add to 1.

In general, Dempster's rule of combination has the following properties:

- (i) Commutativity: $m_1 \oplus m_2 = m_2 \oplus m_1$
- (ii) Associativity: $(m_1 \oplus m_2) \oplus m_3 = m_1 \oplus (m_2 \oplus m_3)$
- (iii) In general, $m_1 \oplus m_1 \neq m_1$. The bpa $m_1 \oplus m_1$ will favor the same subsets as m_1 , but it will do so with twice the weight of evidence, as it were.
- (iv) If m_1 is vacuous, then $m_1 \oplus m_2 = m_2$.

In Bayesian probability theory, evidence is aggregated using Bayes's rule. It is easy to show that Bayes's rule is a special case of Dempster's rule of combination.

Figure 11. Dempster's rule for Example 2



In general, Dempster rule of combination has the following properties:

- (i) Commutativity: $m_1 \oplus m_2 = m_2 \oplus m_1$
- (ii) Associativity: $(m_1 \oplus m_2) \oplus m_3 = m_1 \oplus (m_2 \oplus m_3)$
- (iii) In general, $m_1 \oplus m_1 \neq m_1$. The bpa $m_1 \oplus m_1$ will favor the same subsets as m_1 , but it will do so with twice the weight of evidence, as it were.
- (iv) If m_1 is vacuous, then $m_1 \oplus m_2 = m_2$.

In Bayesian probability theory, evidence is aggregated using Bayes's rule. It is easy to show that Bayes's rule is a special case of Dempster's rule of combination.

Discussant's Response to "AUDITOR'S ASSISTANT: A Knowledge Engineering Tool for Audit Decisions"

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There is much about this article that I like. The focus of this article is on the development of an expert system designed to help the field auditor make more efficient decisions about the level of audit testing required. Both these topics are high on the list of priorities of all of the national accounting firms. A significant portion of the budgets of most major firms is being directed toward the development of personal computer-based expert systems to increase audit efficiency.

The authors recognize the need for the active interaction of the field auditor in the use of an expert system. Too many articles fail to give proper credit to the level of knowledge which resides in the audit engagement team. Firms attempt to keep turnover at the partner, manager and senior levels to a minimum. As a result, audit engagements are frequently staffed by an engagement team with ten or eleven years of total client experience. I believe this paper attempts to give proper recognition to the benefits to be gained by tapping into that experience. The authors stress the importance of understanding the client's business environment. In our firm's approach, we list "Understanding the Business" as the first step of the business review. Although this differs slightly from the authors' "understanding the client's business environment," I believe they both recognize this area as the first and most important step in an audit.

The article is also one of the few which focus on the audit team and the decisions which must be made by that audit team. We need more articles on and research in this important area of audit practice.

Unfortunately, I believe that my negative comments outweigh my positive comments. In summary, I do not believe that the authors are on the right track yet. My general impression of the knowledge engineering tool described in the paper is that it will not be widely endorsed in practice and it may be flawed in theory.

In my view, some of the fatal theoretical flaws of the tool involve a failure to appreciate the complexity of the audit process. Individual pieces of audit evidence frequently impact more than one assertion, and indeed may impact other areas or the entire audit. For example, one piece of audit evidence which indicts the integrity of management may lead either to a qualification or a disclaimer of opinion.

In addition, I do not believe that the authors' system, as described in this paper, gives enough weight to the importance and interaction of individual audit procedures. In Scenario One, the authors indicate revision of the nar from 0.83

to 0.92 based upon discussions with the credit manager on collectibility problems. As a result of this increase, an additional audit procedure which had been planned is not performed. This is even more distressing as the paper does not discuss whether or not any objective evidence other than discussions was used to put the team over the target level of 0.90.

The additional audit procedure not performed is a review of ABC's credit policy. There have been so many instances of audit problems created by changes in a company's credit policy that not to perform such a basic procedure would lead me to question whether the engagement team had obtained an understanding of the business.

From a practical point of view, this type of question would generally not represent any significant time savings. The engagement team did have access to the credit manager. How much longer would the conversation have lasted if the team had asked the credit manager if there were any changes in credit policy? The only way this could represent a significant time savings would be if there had been significant changes in policy. In that case, time savings should not be the driving force because a radical change in credit policy could mean a significant increase in potential uncollectible accounts. This could be true without regard to whether or not the accounts are over 120 days past due.

Also in Scenario One, "the audit team finds the management and accounting personnel to be competent and trustworthy and decides that this evidence supports nar to degree 0.60." Where are the SAS 47 [AICPA, 1983] concepts of inherent and control risk in the authors' equation? I am sure we have all dealt with competent and trustworthy accounting personnel who, because of the existence of significant inherent risk, delivered to the auditors an accounts receivable section which contained a material error. This has frequently been the case where the industry has experienced rapid change such as the oil and gas industry or the savings and loan industry. By neglecting to assess the risk that the balance contains errors that could be material to the financial statements, the authors' belief functions could also be misstated. The article states "the audit team also knows that the maximum risk that nar is materially misstated is only 8%." This would appear to be a very bold statement, given the fact that the allowance for doubtful accounts has not been reviewed. However, even if this statement were true, SAS 39 [AICPA, 1981] would appear to set the limit of audit risk at about 0.05.

The authors appear to either ignore, or fail to understand, the practical role of an audit program. One of the authors' statements is that "at any stage of the audit the auditor has to decide which procedures he or she is going to perform next." This question is generally answered, in practice, by the audit program. The authors' statement that the decision on what to do is taking place during the performance of the audit is simply not true for most audit engagements.

AU Section 311.05 states that "the auditor should prepare a written audit program (or a set of written audit programs)." The audit programs are generally prepared during the planning stage of an engagement. The auditing literature also states that "as the examination progresses, changed conditions may make it necessary to modify the planned audit procedures." I assume that the elimination of planned audit procedures, as a result of changes in the actual versus planned strength of audit evidence represents the core of the authors' "engineering tool."

However, in an actual audit, I believe there would be significant practical problems with the system described by the authors. The system generally requires an assignment of degrees of support to each piece of audit evidence by the audit team. The audit team is described as comprising the audit senior, manager and partner. I know of no present audit engagements which require this much team decision making. On most medium-sized audit engagements, the audit team is not together on a daily basis, or even a weekly basis. Most decisions on the extent of audit procedures are made during the planning and review stages of the engagement. While I agree with the authors that this may lead to a slight degree of overauditing for new clients, for old established clients or for clients in specialized industries, there is probably very little overauditing. There is certainly not enough overauditing to justify the system described in this paper.

Additional comments concerning the "automation of evaluation of evidence" also trouble me. I believe that the degree to which we remove the auditor from the active association with the evaluation of evidence we create audit risk. It is great to see that each piece of evidence, gathered mathematically, increases our degree of confidence. However, such techniques may create the "halo" effect that has been noted in previous academic studies. How questioning will an auditor be if he is examining a piece of audit evidence when his nar equals 0.80? Will he still have the same degree of professional skepticism required?

Many firms presently require an auditor to sign off each program step as it is completed. Each step is separate and distinct, and represents a concrete individual audit unit. Although I recognize that some of the steps give us more audit comfort, each step is important and generally must be performed diligently.

In the paper, statements are made concerning analytical review, client inquiries and confirmation procedures that are very judgmental and unsupported. SAS No. 56, dated April 1988, will require the application of analytical procedures in the planning and overall review stages of all audits [AICPA, 1988]. The required use of analytical procedures was also recommended in the report by the National Commission on Fraudulent Financial Reporting in October 1987. Client inquiries and confirmations vary in effectiveness depending upon the circumstances of the individual client.

Another practical problem created by this article is illustrated by the comment: "The team having reviewed the staff's work makes a judgment that the confirmation provides a 90 percent degree of support for validity and an 85 percent degree of support for the valuation objective." The paper does not address how a team would be able to distinguish such a fine degree of percentage support for each objective. I believe such a fine distinction would not be possible in practice.

Scenario Two provides even more examples of impractical mathematical calculations. In Scenario Two, the engagement team believes that the allowance for bad debts may be understated. They discuss the situation with the credit manager, who also agrees with the assessment that the allowance may be understated. Based upon this information, the support is calculated at 0.80. In my experience, if the client were to agree with the auditor's assessment,

the support would be much higher than 0.80. Clients generally do *not* agree unless there is a problem.

In summary, I believe that the system described in this article will not be practicable. The team concept envisioned by this article is not a workable concept in practice. The system basically ignores the role of the audit program in an audit process and the requirement for preparation of such a program during the planning phase of an engagement. Finally, the system provides far too many chances for an aggressive litigation counsel to question the firm's judgment in the event of an audit failure, and does very little to prevent such a failure.

References

- American Institute of Certified Public Accountants, *Statement on Auditing Standards No. 56*, "Analytical Procedures," AICPA (April 1988).
- American Institute of Certified Public Accountants, *Statement on Auditing Standards No. 47*, "Audit Risk and Materiality in Conducting an Audit," AICPA (December 1983).
- American Institute of Certified Public Accountants, *Statement on Auditing Standards No. 39*, "Audit Sampling," AICPA (June 1981).
- National Commission on Fraudulent Financial Reporting (Treadway Commission) (October 1987).