Review of Expert Systems in Auditing

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The purpose of this paper is to examine the current state of expert systems and decision support systems in auditing. In so doing we will examine completed or prototype expert systems and decision support systems in both external and internal auditing, including special areas of focus such as EDP auditing and governmental auditing.

This paper focuses on those auditing-based systems that have appeared in the literature or have been presented at a conference or of which the authors are aware. There may be some systems that have been developed and are in use, but are not reported here. Generally, that would be because there has been little information on those systems in the literature.

This paper does not provide a general overview of expert and decision support systems. Such treatments are available from a number of sources including Hayes-Roth et al. [1983] and Moeller [1987].

In addition, this paper does not discuss or try to differentiate between expert systems and decision support systems. Both types of systems support audit decision making and, thus, both are included in this paper. The interested reader is referred to Turban and Watkins [1986] for such a discussion.

"The audit environment is a unique and highly complex decision-making environment."

Plan of this Paper

This paper begins with a discussion of the audit environment and then proceeds to review, respectively, audit-based expert systems in EDP Auditing, External Auditing: Academic Systems, External Auditing: Commercial Systems, Governmental Auditing and Internal Auditing. Limitations of auditing-based expert systems are then discussed followed by a discussion of sources for publication and presentation of information relating to expert systems. The final section provides some summary remarks.

The Audit Environment

The audit environment is a unique and highly complex decision-making environment. There are sources of error and inconsistency that are unique to the audit environment. Personal computers and other changes in technology have had and will continue to have an impact on the audit environment. In addition, the audit decision-making environment is process oriented and not results oriented.

Complexity

The audit environment is highly complex. In a discussion of that complexity, Hansen and Messier [1982] note that the audit problem of checking control weaknesses is a "nondeterministic polynomial" problem. This indicates that audit problems have a large number of solutions and that it is difficult to sort through those solutions, in order to chose the best one. Such problems often are solved best by using heuristic approaches to find "good," but not necessarily "optimal" solutions. In the case of audit problems, this generally means using the rules of thumb of experienced auditors. Since such rules of thumb can be included in expert systems, such systems offer an alternative and feasible solution methodology to auditing situations.

Sources of Error and Inconsistency

Holstrom [1984] identifies thirty-two different sources of error and inconsistency. Holstrom [1984, p. 1] states the following:

> Judgment errors occur when there is a departure from a generally accepted criterion. Judgment inconsistencies occur whenever there is a difference between judgments, given the same data set and objectives, regardless of whether a generally accepted criterion exists. An error in overall judgment occurs when the auditor issues an incorrect audit opinion. An inconsistency in overall audit judgments occurs when different auditors render significantly different audit opinions based upon an identical set of financial statements and an identical set of audit evidence. In the latter case, we could determine that an inconsistency has occurred, but we could not conclude which overall judgment is in error unless we know in fact whether the financial statements were materially misstated.

". . . expert systems can be used to improve the consistency of human responses and mitigate errors."

Research (e.g., Hogarth [1985]) has shown that computer programs, such as expert systems, can be used to improve the consistency of human responses and mitigate errors. For example, as noted by Dillard and Mutchler [1987b, p. 17] "Utilization of the ... (expert) ... system will lend consistency, thoroughness and verifiability to the audit opinion decision process."

Personal Computer Environment

One of the primary developments in computing is a shift toward a personal computer (PC) computing environment. Researchers (e.g., O'Leary [1986]) noted that the change to the PC environment can have a major impact on auditing. First, the PC allows the user to take computing power with them to various locations. As a result, expert systems can now be developed to support the auditor in the field. Second, since so much work is now done on PC's there is increased need to be able to audit in a PC environment. Thus, expert systems can be used to bring auditing knowledge to the auditor for the audit of PC-based systems.

Changing Technology

Holstrom et al. [1987] identified "... numerous trends that are likely to have a major impact on audit evidence, the audit process and the role of auditing in the next 10 to 15 years." They summarized the changes in information technology in four different categories: Office Automation and Transaction Automation, Data Communications, Computer Hardware and Computer Software.

Their initial results indicate an increased use of expert systems in auditing in the future, as exemplified by some of the applications discussed latter in this paper. In addition, it is likely that expert systems be used to mitigate some of the problems resulting from, e.g., the move toward a paperless society. The "Law of Requisite Variety" (e.g., Ashby [1965]) notes, it takes equivocality to remove equivocality. Accordingly, as there are changes in complexity in those four categories, the systems needed to process information from those systems also must be more complex.

Process Oriented -- Not Results Oriented

Many problems in auditing do not have feedback mechanisms that provide for the recognition of correct or incorrect responses (Kelly et al. [1987]). As a result, instead of

being results oriented, auditing is process oriented. The quality of the work is not judged by results, but by the record of the process as summarized in the work papers.

Expert systems can be used to promulgate a particular process and record work done in that process. Thus, they can provide uniform documentation of the process and act to defuse knowledge to the auditors.

Previous Surveys

There have been a number of other surveys of accounting and audit-based expert systems and decision support systems in academic outlets, e.g., Amer et al. [1987], Bailey et al. [1987], Bedard et al. [1984], Borthick [1987], Chandler [1985], Dillard and Mutchler [1984], Messier and Hansen [1984] and O'Leary [1987]. There have also been a number of surveys of audit-based expert systems in professional outlets, e.g., Bailey et al. [1986], Borthick and West [1986], Elliot and Kielich [1985], Flesher and Martin [1987] and McKee [1986]. However, these surveys generally have ignored intrusion detection type systems, internal auditing and governmental auditing. In addition, there has been a structural change in the development of expert systems since those papers were written. The first reports of expert systems in auditing were almost entirely from academics. Now, it seems that many of the systems that are generating the most interest are systems developed for commercial purposes.

These commercial systems differ from systems developed by academics in a number of ways. First, they are not just developed to see if such a system can be developed. They generally are designed with the idea that they ultimately will be used. Second, commercial ventures usually entail the use of greater resources then can be mustered in most academic-based expert system developments. Third, in commercial efforts, the application is dominant. Methodology issues, design issues and other research issues are the primary focus of many academic systems.

EDP Auditing

Expert systems developed for EDP auditing take two primary formats. One approach is that to develop an expert system to assist the auditor in auditing the system. Another approach is to develop systems that audit use of the system, in order to determine if there has been intrusion into the system.

Auditing General EDP Systems

There is really only one system that has been developed to assist in auditing general EDP systems. That system, EDP-XPERT has been described in two primary papers (Hansen and Messier [1986-a, 1986-b]), which, respectively, describe the system and the validation efforts that were given the system.

EDP-XPERT was one of the first auditing-based expert systems on which development efforts initiated. Early discussion of that system was given in Hansen and Messier [1982] and Messier and Hansen [1984]. EDP-XPERT was developed using the rule-based, expert system shell AL/X.

A sample rule from EDP-XPERT is as follows (Hansen and Messier [1986-b]):

If 1) Message Control Software is Complete and Sufficient, and
2) Recovery Measures are Adequate, and
3) Adequate Documentation is Generated to Form a Complete Audit Trail,

Then There is strong suggestive evidence that controls over data loss are adequate.

This system demonstrates that rule-based expert systems can be used to aid the auditing of internal controls in EDP systems. However, as noted in a related inquiry, Biggs et al. [1987] found that EDP auditors generally do not use "if ... then ..." rules of the above type exclusive of such systems. Alternatively, such rules may be constructed from knowledge acquired from those auditors.

Specific EDP-Based Applications

MIS Training Institute has developed a number of "expert systems" to assist internal auditors. Currently, there are seven applications available, four of which are based on IBM systems. Those four systems focus on CICS (based on IBM's communications system), System/36" and "Expert Auditor System/38" (two IBM minicomputers) and IMS (IBM's database environment). While, three of the systems are more general. Those systems are concerned with data center reviews, disaster recovery and auditing microcomputers. Each of the systems apparently makes use of a sequence of interrelated questions.

Each of the systems they have developed reflects at least three of the guidelines of a "good" expert system application (for example, O'Leary [1986]), thus providing empirical support for those theoretical observations. In particular, each system is based on a set of audit concerns about highly specific environments, each of the systems are the concern of a large number of auditors, each system operates in a PC environment and each of the applications are in areas that require a substantial amount of specific expertise.

"An important aspect of auditing EDP systems is ensuring their integrity."

Intrusion Detection Systems

An important aspect of auditing EDP systems is ensuring their integrity. Expert systems have been designed to provide continuing, on-line "intrusion - detection" protection of EDP systems. Such systems are resident in the computer system, monitoring the behavior of system users.

Denning [1987] has discussed such a system designed to protect the operating system. That system is based on the hypothesis that exploitation of systems involves abnormal use of the system. Thus, by detecting abnormal use of the system, security violations can be detected. There are a number of examples of such violations, including the following (Denning [1987], Richard [1983]).

Attempted Break-in: *Someone attempting to break-in to the system likely would generate a large number of illegal passwords.*

Successful Break-in: *If an illegitimate user successfully breaks into a system then they may have different location or connect time than the legitimate user on whom's account they have accessed the system.*

Penetration by a Legitimate User: *A legitimate user interested in penetrating the security of the system might execute programs different from or in a different order than would be expected.*

Leakage by a Legitimate User: *A legitimate user that attempts to leak unauthorized data might employ a remote printer, not normally used, at a time of the day that also is unusual.*

Virus: *A virus may cause an increase in the storage used by executable files or an increase in the frequency of execution of files.*

Typically, normal behavior is represented using profiles for each user or facility. Then current behavior is compared to those profiles to determine if it is normal or abnormal.

A research area with substantial potential impact is making such systems more efficient and effective. This research requires the investigation of the efficiency of different intrusion detection strategies. Generally, this means determination of those variables that best signal intrusion and those means (for example, statistical) that best determine the levels of those variables that indicate intrusion. Further, it is unclear what the impact of context (a given firm) is on both variables and methods of investigation. In addition, it is unclear what is the organizational impact of such systems. For example, if intrusion-detection systems are used, do human "detectors" continue to function or do users just say "oh, the system does that."

Academic-Based External/Internal Auditing Systems

Projects of concern to internal and external auditors have received the most extensive attention. In this area there have been a number of applications, including:

Adequacy of Allowance for Bad Debts -- Chandler et al. [1983], Dungan [1983], Dungan and Chandler [1983, 1985], Braun [1986]

Audit Planning -- Kelly [1984, 1987]

Going Concern Process -- Biggs and Selfridge [1986], Selfridge [1988], Selfridge and Biggs [1988] and Dillard and Mutchler [1986, 1987]

Internal Controls -- Meservy [1984], Gal [1985], Meservy et al. [1986], Bailey et al. [1985] and Grudnitski [1986]

Materiality -- Steinbart [1984, 1986]

Risk Assessment -- Mock and Vertinsky [1984, 1985], Dhar et al. [1987] and Peters et al. [1988]

Adequacy of Allowance for Bad Debts

The first audit-based expert system was developed by Dungan [1983] (see also Dungan and Chandler [1983, 1985]) to analyze the problem of the adequacy of the Allowance for Bad Debts for large commercial clients, based on analyzing the accounts individually. The system, entitled AUDITOR, was developed using the rule-based expert system shell AL/X.

AUDITOR gives advice in the form of an estimate of the probability that a given account balance will prove to be uncollectable. That research study had as (Dungan [1983]) "... its objective the creation of an expert system model of certain judgment processes of auditors."

A second prototype expert system, is currently in being built by Braun [1986]. In some respects it is an extension of AUDITOR (Chandler et al. [1983]). However, the emphasis of the Braun [1986] study is on the hospital industry. In addition, it also considers the combination of analytical and judgmental variables.

As noted by Dillard and Mutchler [1987], output from systems like the one described here could be used as input to other systems in order to take advantage of development efficiencies.

Audit Planning

Kelly [1984, 1987] developed a prototype model ICE (Internal Control Evaluation) to aid in the audit planning process. ICE featured a knowledge hierarchy of three different levels. The first level included knowledge about the industry, economy, management and the audit history. The second level focused on the client environment, the organization, planning manuals and accounting procedures. The third level focused on internal control functions in the purchasing process.

ICE was developed using LISP. Unlike most expert systems, ICE made use of both frames and rules.

"The going concern problem is one of the most difficult facing auditors."

Going Concern Process

The going concern problem is one of the most difficult facing auditors. As noted by the AICPA [1988] "in order to render a going concern judgment, the auditor must 1) recognize that a problem exists, 2) understand the cause of the problem, 3) evaluate managment's plans to address the problem and 4) render a judgment on the basis of whether the problems are sufficiently serious and whether management plans are judged to succeed."

There have been at least two ongoing academic efforts to address the going concern problem. Both the work of Biggs and Selfridge and the work of Dillard and Mutchler can be traced in a series of papers describing the systems change over time.

Probably one of the most sophisticated accounting and auditing expert systems is GCX (Going Concern Expert) discussed in a sequence of papers by Biggs and Selfridge [1986], Selfridge [1988] and Selfridge and Biggs [1988a, 1988b]. GCX was programmed in MacScheme, a dialect of Lisp, that runs on an Apple Macintosh II. GCX was tested on five years of data from a real world company, about which the auditors who were questioned had substantial knowledge.

The research questions addressed in the development of GCX included (Selfridge and Biggs [1988a, p. 2]):

What are the categories of expert knowledge and how are they represented?
What are the reasoning strategies of the expert auditors and how are they represented?
How is the knowledge and reasoning strategy organized in GCX?

In Biggs and Selfridge [1986], the system included expert knowledge in measures of financial performance, business and the business environment, and management plans. GCX had 100 financial reasoning rules and 80 business and business environment events.

In Selfridge and Biggs [1988a], it was reported that there were six categories of knowledge, including events, inter-event causality, company function (financial model and operations model), events/financial performance causality, measures of financial performance and going concern problems. In that model there were 140 event frames and 215 entity frames.

The model summarized in that paper employs Schank's [1982] MOPs (Memory Organization Packets). For example, in the operations model there is a hierarchy of MOPs that employ successively more detailed descriptions of company operations.

In Selfridge and Biggs [1988b], that knowledge was extended to general financial knowledge, of actual events, knowledge of normal events, knowledge of company function, knowledge of company markets, knowledge of the industry, knowledge of multiple business lines, knowledge of changes over time and knowledge of other companies.

In addition, to addressing the issues specified by the authors, the sequence of papers that reflect the development of GCX allow insight into the growth and development of an expert system.

Dillard and Mutchler [1986, 1987a and 1987b] also have done extensive work in the area of modeling the auditor's going concern opinion decision. Their system was developed on a DEC 2060 using a menu shell, XINFO. The system apparently employs approximately 450 decision frames or nodes in a decision tree. The intelligence in the system is in the decision structure and hierarchy.

The system contains "technical" knowledge about such things as basic accounting procedures, audit procedures, audit standards and the business, economic and legal environment in the context of a "task support system." This knowledge is organized in a hierarchical branching structure with nodes representing primitive and intermediate decisions. Technical knowledge was gathered in each of seven categories: operations, financial, market, management, industry, audit and other.

The system uses a system architecture that interfaces that task support system with three other components: task action system, external interface system and a guidance system. The task guidance system uses frames to provide suggestions and, rules and methods for making decisions specified in the task support system. The task action system supports programs for data access, statistical analysis and other additional tools that the auditor may wish to use. Finally, the external interface system allows for the generation of documentation and audit trails.

The system does not exactly mimic expert behavior. For example, the system employs numeric rating systems that it is unlikely auditors use in going concern problems.

Internal Controls

TICOM (Bailey et al. [1985]) was the first auditing-based system to implement artificial intelligence techniques in the system. TICOM (The Internal Control Model) is an analytic tool that aids the auditor in modeling the internal control system and querying the model in order to aid the auditor in evaluating the internal control system. TICOM was implemented in Pascal.

Materiality

Steinbart [1984,1986] developed an audit judgment model, AUDITPLANNER, for the assessment of materiality. AUDITPLANNER uses six different sets of inputs to aid in the materiality decision: prior year's materiality levels, financial characteristics of the client, nonfinancial characteristics of the client, future plans of the client, nature of the audit engagement and the intended uses of the client's financial statements.

The system was built for profit and not-for-profit firms. The test clients included manufacturing firms, trucking firms, super markets, a school district and a Boy Scout Council.

AUDITPLANNER was built using the rule-based expert system shell, EMYCIN. The system did not include the use of certainty factors.

Risk Assessment

Substantial literature of risk assessment exists (e.g., Mock and Vertinsky [1985]). However, there are a number of problems where it is difficult to quantify risk. As a result, Dhar et al. [1988] describe "... the problem of risk assessment as knowledge-based, where knowledge about the client' history, recent events specific to the firm or industry, and knowledge about the internals of a firm are crucial in shaping the auditor's judgment about risks associated with accounts, and hence the audit plan." This interpretation is further enhanced by the general finding (Mock and Vertinsky [1984, p. 1]) that people are "not good intuitive statisticians and therefore the craft of risk assessment is fraught with risks."

There is at least one paper on the use of risk assessment in auditing decision support systems (Mock and Vertinsky [1984]) and at least two papers in the use of expert systems in assessing risk (Dhar et al. [1987] and Peters et al. [1987]).

"The smart questionnaire approach ensures that the auditor performs certain procedures."

External Auditing: Commercial-Based Systems

Arthur Anderson

Arthur Anderson (AA) has developed expert systems for the consulting group's clients, e.g., Arthur Anderson [1985] and Maui and McCarthy [1987]. However, there have been no discussions in the literature relating to internal projects to aid the AA auditing process.

Arthur Young

Arthur Young (AY) has taken a single product, multiple component, middle-out strategy in the development of their decision support system, AY/ASQ. AY/ASQ is software designed to automate the audit process for manufacturing environments.

AY/ASQ was developed in an Apple MacIntosh environment. The operation for each of the applications is similar to the other applications. The system consists of several modules including Decision Support, Office, Trial Balance, Time Control and Databridge.

The decision support module features the ability to reference the computer file stored documentation for the AY audit process. In addition, the system guides the audit planning process through a "smart questionnaire" approach. This smart questionnaire approach ensures that the auditor performs certain procedures. When those procedures have been followed, the computer updates the rest of the checklist.

Future enhancements likely will include the development of similar modules for different industries and the development of a module to analyze internal controls.

Peat Marwick Main

Peat, Marwick, Main & Co. (PMM) apparently has taken a multiple project approach to the development of expert systems in auditing. Their best known system is Loanprobe, also known as CFILE. The development of that system is chronicled in a sequence of papers, including Kelly, Ribar and Willingham [1987], Ribar [1987, 1988a, 1988b, 1988c]. CFILE is a rule-based system developed using INSIGHT II (now Level V). A rule-based approach is used because of the classification nature of the problem. (Similar classification problems have been solved using a rule-based approach.) It is estimated that CFILE has three person - years of development time (Ribar [1987]).

CFILE derives its name from credit file analysis and is designed for use in bank audits loan loss evaluation. In particular, it aids the process of estimating the dollar amount of the reserve for the banks portfolio of loans.

AUDPREX (Kelly [1986]) is a proposal to develop an expert system to aid in the design of audit programs in the area of inventory systems. Such a system would be used as an aid to determine the type, timing, nature and the amount of substantive procedures.

In contrast to CFILE, another system, designed to aid in interpretation of SFAS #80 on accounting futures, was done by a single researcher within a period of several weeks (Ribar [1987]). That included the time required by the researcher to learn the expert system shell, INSIGHT II. For the SFAS-based system, the professional literature provided much of the guidance.

"Even if humans could process all the volume, often budgetary constraints limit the number and quality of persons that could be employed."

Price Waterhouse

There are no systems reported at Price Waterhouse (PW). However, PW recently has developed a Technology Center. At the Technology Center, PW is exploring the use of multiple technologies in auditing, including the use of decision support systems and expert systems.

Governmental Auditing

Governments face the problem of auditing and reviewing large volumes of tax returns and filings of various types. The large volume often means that humans are unable to process all the documents in a cost - effective manner. Alternatively, even if humans could process all the volume, often budgetary constraints limit the number and quality of persons that could be employed. As a result, the need for systems aimed at processing similar documents submitted to the government is likely to be very high. The successful development of the following systems indicates that such systems may be widespread in the near future.

Each of the following systems has been developed as either a consulting project or as an activity of an internal artificial intelligence staff.

Reviews of SEC Filings

Currently, human financial analysts use analytic review of corporate filings at the Securities and Exchange Commission (SEC) to check the correctness of the filings. Arthur Andersen & Co. [1985] (see also Mui and McCarthy [1987]) developed Financial Statement Analyzer (FSA) as a LISP-based prototype to explore the possibility of using a computer program to compute and analyze ratios. FSA includes the ability to "understand" the text in the filings so that it may gather relevant information required to complete an analytic review of the return. Such a system would limit the need for human financial analysts to perform those activities and free their time up for other activities.

From a research perspective, this system is one of the first functioning systems to employ the approach summarized in DeJong [1979] to read and understand natural language. Briefly, that approach reads a part of the sentence. It then predicts what will follow in the remainder of the sentence. Then it checks its prediction against what it actually finds to confirm and guide its search for meaning in the rest of the text. The system continues in this manner, predicting and substantiating while generating its understanding of the text.

Pennsylvania State Audit for Taxes

Hall et al. [1987] address the problem of determining "Which Organizations should be audited to achieve the maximum collection of monies due to the state of Pennsylvania?" Accordingly, the overall audit goal is to improve audit productivity.

Unfortunately, this problem is difficult to solve since there is little understanding about which organizations should be audited. Thus, there is little available expertise to build into the system. As a result, Hall et al. [1987] developed a system that would learn and develop the necessary expertise.

The general research goal of the paper is to determine how a computer program can be programmed to learn. In order to accomplish that goal they chose a genetic learning approach. Genetic algorithms learn by employing different combining rules on responses, such as inversion and mutation. For example, the system may combine the two sets of characteristics abc and cde to form abe, in its search for a better set of characteristics.

IRS Auditing of Tax Returns

A recent publication by the Bureau of National Affairs in 1987 indicated that the Internal Revenue Service's new artificial intelligence lab is exploring new systems to identify likely tax returns for examination potential. Very little has been released on their efforts to-date. However, they face a problem similar to other government activities, in that they have a number of documents to process in a short time and are subject to budgetary constraints. Further discussion of IRS use of expert systems is found in Brown [1988].

Danish Customs Auditing of Value Added Tax (VAT) Accounts

Recently, Danish Customs Authorities employed a consulting firm to develop an expert system to help them audit VAT accounts Lethan and Jacobsen [1987]. The system was designed to develop more effective VAT auditing and to improve the VAT examiner's productivity. As in other government applications, there is a great deal of work to be done and the expert system is designed to do some the work in order to improve the productivity of the examiners.

To acquire the knowledge necessary for the system, the knowledge engineers found that they almost had to become "experts" in the VAT auditing process. Further, for the system to be used by Danish Customs officers at the sites of the companies that were being investigated the system would have to be developed for use on an IBM-PC and the knowledge base would have to be in Danish.

The system is a prototype that is designed for release in 1988. The system was developed using the expert system shell, KEE.

Contributions and Extensions of Government Audit Systems

Each of these systems is important because they capture the knowledge of experts in their knowledge bases and allow for productivity improvements. Each of these systems is designed to allow computer processing of some human information processing activities, while allowing humans to focus on other more important issues.

However, there are additional contributions. The FSA was one of the first actual implementations of DeJong's [1979] approach to understanding text. The Pennsylvania State Tax system is the first audit system to be able to learn. The VAT system demonstrates an easy to forget capability of expert systems that the knowledge does not

have to be recorded in English -- the system does not care what language the knowledge is in.

Systems of this type are not limited to these applications. Instead, those situations where there are a large number of documents to process and those situations where there is interest in determining file violations are all conceptually congruent with these applications. In addition, although each of these applications is associated with a government, such applications are not limited to government but could be extended to almost any business that processes large amounts of the same kind of documents.

Internal Auditing

The functional area of auditing that probably has received the least attention is internal auditing. Although internal auditors will likely make use of many of the developments in each of the other categories discussed above, some applications have been aimed at the unique requirements of internal auditing.

Decision Support for Internal Audit Planning

Boritz [1983] presented an initial report on the development of a desktop decision support system for internal auditing planning. That system (Boritz [1986-a]) is available to the commercial market through the Institute of Internal Auditors (IIA) as a product known as "audit MASTERPLAN" (AMP).

AMP includes two approaches to measuring risk (Based on Boritz [1986-b]) and includes the IIA's Standards for Professional Practice of Internal Auditing. AMP is designed for most industries (financial, industrial, service and manufacturing). AMP has five components: Systems Management, Risk Factors Management, Audit Portfolio Management, Personnel Skills Management and Long-term Planning and Budgeting Module.

In the original report (Boritz [1983]), the research focus was on the user interface and the inclusion of knowledge into the procedures of the system rather than the storage of a separate knowledge base. Boritz and Kielstra [1987] described a methodology for the assessment of risk, using audit and inherent risk.

". . . the research focus was on the user interface and the inclusion of knowledge into the procedures of the system rather than the storage of a separate knowledge base."

Price Analysis

A problem that continues to make headlines throughout the country is the spending activities of the federal government, e.g., the two hundred dollar ashtray. In a sequence of at least three papers Dillard et al. [1983,1987] and Ramakrishna et al. [1983] proposed the development of an expert system to aid in the examination of the reasonableness of an expenditure.

Their discussion is primarily aimed at federal government acquisitions. However, as they note, price analysis is also a problem in private enterprise.

PAYPER -- An Expert System to Examine Payroll and Personnel Files

Payper (Payroll - Personnel) is a prototype expert system, developed using the expert system shell EXSYS, designed to aid in the audit of payroll and personnel files (O'Leary and Tan [1987]). It does this by ensuring that conditions within each field of each record meet certain conditions and that the analytical relationships that hold between fields meet certain conditions. For example, not only should hours worked and pay rate meet certain constraints, but also hours worked times pay rate plus vacation pay must meet certain constraints.

The primary theoretical contribution of PAYPER is that it uses traditional expert systems, multiple conditions rules, to extend traditional EDP single field audit tests. By taking into account relations between the fields, this approach allows tighter and more comprehensive analysis of the data.

The Internal Audit Risk Assessor (TIARA) -- The Equitable

There is only limited information available on TIARA as developed by Inference Corporation for The Equitable. A brief summary of the system is available (Inference Corp - No Date) and further inquiries to Inference Corporation did not yield any additional information, except that the system was not used by The Equitable.

As originally discussed TIARA presents a methodology for assessing risk. Some of the variables used in that decision include strength/experience of the units management team, the unit's internal control consciousness, changes in the unit's basic industry/market and the length of time since their last audit. The system was designed to provide a means to enable rapid identification of high priority audits and consistent assessment of audit risk.

Coopers & Lybrand -- Internal Audit Systems

Recently, Coopers & Lybrand have begun promoting a general internal audit system that

- Employs Audit Planning and Tracking
- Allows Automatic Sample Selection from Mainframe Data
- Automatically identifies Patterns in Sample Data
- Has Intelligent online questionnaires for policy testing and specific regulation
- Provides explanations for questions
- Records internal auditor comments during the audit
- Displays policy documents online
- Generates Work Papers
- Prints branch exception reports

Continuous Audit of Online Systems

Vasarhelyi et al. [1988] argue that recent advances in hardware and software technology are engendering increasingly complex information systems environments, thus, requiring increasingly complex audit approaches. Tener [1986] suggests that audit management utilize decision support systems, management information systems and management science models to identify and project the deterioration of controls that can occur between audit engagements. Further, as firms increase in size, because of mergers and economies of scale, the quantity of auditing demands on the auditor is increasing.

However, the same technologies that increase the complexity of the information systems environment can be used to the advantage of the auditing those systems. Not only can decision support systems be used to assist auditors, but the computer can be used to perform additional auditing. In particular, because of the large amount of data, auditors may not be able to provide an effective or efficient audit. As a result, it is desirable to build systems that continuously audit portions of the database as transactions occur.

"Audit management (should) utilize decision support systems, management information systems and management science models to identify and project the deterioration of controls that can occur between audit engagements."

The quality of these audit systems is dependent on the ability of the modeler to capture the expertise of auditors in the metrics and analytics used to model that expertise. Research in systems of this type needs to explore approaches that capture that expertise best.

Fraud Detection

At least two studies (Tener [1988] and Lecot [1988]) have used expert systems to investigate the possibility of fraud as part of the internal audit function.

Tener [1988] discusses an off-line fraud detection system for deviant file use. Lecot [1988] describes an on-line system designed to determine fraudulent credit card use. In each case the focus of these systems was on determining if a user of a service of the firm is a legitimate user. Conceptually, the intrusion detection systems discussed under EDP systems and the continuous audit system discussed immediately above are similar to these systems.

The approach of each system is to first establish a profile for each of the legitimate users, that defines expected and possible behaviors. Then when that user makes use of the system, that use is compared to the profile to determine if the user is who they say they are. Those comparisons are based on the notion that "early warning symptoms" can be captured in those user profiles.

Dangers In Expert System Development

One of the dangers of the current approach to most knowledge engineering projects is the preoccupation with what is, rather than what should be. On one expert system project of which the authors are aware, it was realized that a mathematical programming approach (integer programming) would provide a better solution to a subproblem in the system than using a sequence of if-then rules. The linear program was able to provide a better solution than simply mimicking an auditors behavior. There is no need to use satisficing procedures when optimal solution generation processes can be used.

Preoccupation with the type of knowledge representation can be dangerous. For example, as Biggs et al. [1986] found auditors do not think in "If ... then ... " rules. Turning dialogues with auditors into such rules may lead to a loss of information.

In a related study, Gal and Steinbart [1986] examined the development of two expert systems for investigating the nature of audit judgment. The evidence presented in that paper indicates that "refinements made to those prototype systems resulted in evaluations which reflect more of the decision criteria actually used by the auditor." That is, the initial systems developed may not properly represent judgment.

Another danger in the development of expert systems is that the more that computers do the less that auditors need to do. This has at least two implications. First, we must remember that expert systems are a move to automate the audit process. As with the introduction of all automation projects, the number of human workers decreases. Thus, we can expect to see a decrease in the number of auditors to accomplish the same amount of work. Second, if the system knows something then the auditor may not need to know that something. As a result, auditors may forget important information that they have learned or not learn things that are important. Reportedly, AY has tempered the inclusion of activities in AY/ASQ so as to minimize the negative implications of the system knowing "too much," and the auditor forgetting or worse yet, not learning.

Another danger is that the auditor would blindly depend on the systems' recommendations. This could occur in at least two situations. First, if the auditor does not have the necessary base knowledge then decisions made by the system cannot be questioned. Second, if the auditor does not "interact" with the systems then the systems suggested

"One of the dangers of the current approach to most knowledge engineering projects is the preoccupation with what is, rather than what should be."

course of action will be executed. As a result, it is important to place the responsibility for the actions on the auditor, not the system.

Further, there are security problems associated with expert systems that are different than those associated with other computer-based systems. Such security problems are discussed in O'Leary [1988c].

Sources of Expert System Contributions

Auditing: A Journal of Theory and Practice, has become a primary source of publication of academic papers on expert systems in auditing. *The Expert Systems Review*, published by the University of Southern California, School of Accounting, is a publication aimed at disseminating information about expert systems in accounting and business. It provides more of a focus on expert systems and other advanced technologies in general, rather than just expert systems in auditing systems.

"Expert systems remain an important tool to simulate the procedures that an auditor goes through . . ."

Three primary meetings have fostered the presentation of results on expert systems in auditing and accounting. The University of Southern California and Deloitte, Haskins & Sells have sponsored "Audit Judgment Symposia" which have featured the first presentation on many of the systems discussed in this section of the report. This is clearly established by reviewing the references. In addition, the Measures in Management College of The Institute of Management Sciences has also featured initial and subsequent discussions on many of the papers listed in the references at the semi-annual meetings of the Operations Research Society of America / The Institute of Management Sciences. In the fall of 1988, the University of Southern California and Peat, Marwick, Main Foundation sponsored the First Annual International Symposium on Expert Systems in Business, Finance and Accounting. Many of the papers from that meeting were published in the *Expert Systems Review*. Plans have been established for holding annual Expert Systems Symposia in Business, Finance and Accounting into the foreseeable future.

As the major accounting firms started developing their own statistical audit software, they made it available to universities so that they could integrate it into their programs. At least one of the firms, AY, is considering allowing distribution of their software to academic institutions. This tendency is likely to continue with other firms following suit.

Conclusions

Recently developed audit-based expert systems have moved beyond the initial rule-based systems to include such knowledge representation schemas as frames and semantic networks. The systems go beyond just employing heuristics in the context of decision making processes, to include developments, such as learning and natural language understanding. In addition, expert systems have moved out of academe and into commercial applications.

As summarized in this paper, a wide variety of prototype and commercial systems are in operation. Thus, from an academic perspective there is no more need to build expert systems to show that they can be used to solve accounting problems.

However, expert systems remain an important tool to simulate the procedures that an auditor goes through, to test our understanding of the knowledge in a particular area of auditing, to test the use of technological developments in artificial intelligence in auditing-based expert systems,

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