# AI Integration for Enhanced Decision Support

Paul R. Watkins, Thomas W. Lin, Daniel E. O'Leary

Advanced Technologies in Information Systems, University of Southern California

## ABSTRACT

The topic of integration of Artificial Intelligence with traditional MIS and DSS has generated interest and attention over the past few years. As applied AI has matured and developed beyond Expert Systems to include Neural Nets, Genetic Algorithms, Model Based Systems, Fuzzy Logic, Natural Language and Case-based Reasoning, the need to provide perspective for the integration of these AI technologies with each other has become an issue of interest and concern.

This paper provides a perspective that is problem driven and suggests that AI integration is a matching process of problems/sub-problems with appropriate AI or other problem support technologies which then can be integrated to provide enhanced decision support.

AI integration is demonstrated within the context of Internal Control evaluation where the emphasis is on detecting/preventing financial fraud.

## 1: Introduction

Integration of applied artificial intelligence and decision support systems has been a topic of interest for a number of years beginning with the framework set forth by Turban and Watkins [6]. In this framework the comparative advantages of Expert Systems, the most viable AI technology at that time, and decision support systems were compared and discussed. Several approaches for the integration of ES and DSS were described. Later, Watkins and O'Leary [8], [9] developed a Views model for AI integration which suggested a number of approaches to the integration of information systems and applied artificial intelligence. The "views" ranged from hardware and software views to problems/decisions, organizational, support and others. The framework of the Views model suggests that AI integration is multi-dimensional and more than the commonly discussed software integration.

As AI research and development efforts have progressed over the past few years, other AI technologies in addition to expert systems and knowledge based systems are becoming potentially useful in MIS/DSS domains. These AI technologies include Neural Networks, Fuzzy Logic, Model Based Systems, Genetic Algorithms, Case-based reasoning approaches and other machine learning approaches and refinement of natural language parsing and processing. Although each of these technologies can be integrated with MIS/DSS on an individual basis and frameworks such as Turban and Watkins [6] and Watkins and O'Leary [8], [9] can be altered to accommodate these new technologies, there is no capability of addressing the issue of under what circumstances a particular AI technology is "best" or "desirable". A number of comparative studies are now being presented and published which compare such AI technologies as Expert Systems and Neural Nets [7], Neural Nets and Statistical Methods [1], [5], Cased-based reasoning and Expert Systems [4], Cased-based reasoning and statistical methods [3], Case-based reasoning and neural nets [2]. These studies are useful and provide insights into the relative merits of these newer AI technologies. One implication of these research studies is an *"either or"* notion. That is, one may feel that the issue is to use *either* an expert system *or* a case-based reasoning system or *either* a neural net *or* an expert system.

The purpose of this paper is to provide a perspective which suggests that the issue may not be *either or* but rather *where does it make most sense to use a particular AI or other problem addressing method.* Thus, the focus of the paper is on the integration of various AI and other problem addressing technologies with each other to provide enhanced decision support systems.

The sections that follow describe the AI components which are of potential use in DSS and provide a discussion of a research project which has focused on development on an integrated decision support system for the assessment of internal controls relative to the detection and prevention of financial fraud.

## 2: Integration of AI components with each other and within DSS

Several AI technologies are of potential of use in a decision support setting. These include: rule based systems, frame based systems, neural networks, case-based reasoning, model based reasoning, fuzzy logic, natural language processing and genetic algorithms.

**Rule-based** systems are those with a knowledge base component consisting of conditional IF - THEN statements which are generally "chained" together through some appropriate method of inference. The rules, once established in the knowledge base are static, non-adaptive and function identically in repetitive dialogues for a given problem/decision domain.

**Frame-based** systems are those which have a knowledge base consisting of concepts represented in object hierarchies with higher order concepts subsuming lower order concepts. Rules may be present in these systems but the knowledge base is predominately comprised of frames/concepts.

**Neural Networks** are algorithms for detecting patterns in large amounts of data. The idea behind a neural network is that for a given set of inputs and a desired set of outputs (to and from the neural net) a mapping relationship is established that enables new input data to be properly classified or identified according to the output criteria. Neural nets look at the relationships implicit in the data and develop a predictive model for use with further data. Neural nets do not provide criteria equivalent to statistical methods for evaluating the underlying model. As such developing an appropriate neural net tends to be more of an art and requires a great deal of data and "tinkering" with the model to achieve a satisfactory predictive model. Neural nets appear to have very good predictive and classification abilities in a variety of domains. Unlike expert systems they offer no explanation or provide insights into how the end result or solution is achieved.

**Genetic Algorithms** allow machine learning and natural selection to take place especially in neural networks and to facilitate adaptability of the networks to adjust to new situations. Genetic algorithms are still somewhat developmental and experimental but appear to have potential to provide learning capability to neural networks and other kinds of algorithms.

**Case-based Reasoning** is based on the notion of that past experiences and case histories can often provide insights into future decisions/problem solving. A case is any set of features or attributes that are related in some manner and to which a comparison can be made of a current situation. The basis for the comparison is similarity -- to what extent is the current situation similar to or analogous to prior situations (cases). The criteria for assessing similarity is varied and is a topic of current research. Similarity criteria include: nearest neighbor techniques, inductive techniques (ID3) and hybrid techniques which may include some elements of knowledge/intelligence. The challenge in case-based reasoning is to establish appropriate indices that allow comparison between and referencing of the various cases and the current scenario/situation. Case-based reasoning is not as restrictive as rule-based systems in the sense of having to work out all the paths in the rule base prior to utilizing the system. Case-based reasoning also can provide some adaptiveness to new situations and modify the case-histories based on new information. Case-based reasoning systems have been substituted for expert systems, neural nets and other machine learning approaches.

**Model-Based Reasoning** is different from expert systems in the sense that the knowledge base is not represented in terms of rules or frames but rather in the form of a model. The model may be an abstraction of a human expert or a mathematical or other structured model which can provide problem/decision solution support. Model based reasoning may be an extension of management science/operations research techniques or it may involve other model forms or abstractions. The idea is that rather than represent the state of the world for a given domain in terms of IF -- THEN conditional statements which are logically related, we form an abstraction of the problem domain and its solution and provide the decision maker with the model based support tool.

**Fuzzy Logic** based systems are those in which the inference mechanism for dealing with uncertainty is not restricted to certainty factors, probability, scoring models or other common methods based on Aristotelian logic. Rather, with fuzzy logic which is based on fuzzy set theory, an attribute or item can have partial membership in more than one set and in sets which appear to be contradictory. In essence, fuzzy sets may represent a continuous range of possible states for values in and out of sets which are numerically represented. Fuzzy systems often include rules from expert systems and attributes of neural nets. Thus they can process structured knowledge numerically.

**Natural Language Processing** is an older AI technology which has been envisioned as a key element in DSS. Natural language processing continues to improve in terms of parsing capabilities and although far from natural in a human sense has had some impressive successes in a variety of applications, particularly in text recognition systems.

The key idea for AI Integration is that it be top-down, problem/decision oriented. That is, the problem or decision issue should drive the decision aid or DSS consideration. Often in AI domains the reverse is true. For example, knowledge of expert systems may suggest that an expert systems approach is attempted for most of the problems which require AI support. Or, more recently, interest in neural nets may suggest that a neural network approach should be tried in domains of AI interest. In finance and accounting an issue of concern has been that of fraudulent financial reporting and the maintenance of appropriate controls within organizations to prevent/detect such financial abuses. A number of research studies and development efforts have attempted an expert systems solution approach in this domain. The idea is that a rule or frame based system could be developed to model the system of internal controls and thus provide a decision aid for this crucial domain. Most of these efforts have not been successful due to the complexity of the domain and the inability of an expert systems approach to provide a satisfactory solution.

## 3: Prototype integrated intelligent support system

The following is a summary of the objectives and approach that were taken to develop a conceptual model and operational prototype for an intelligent support system to aid in assessing the system of internal controls with respect to financial fraud and other sources of error. The conceptual model started with the premise of: what is the problem(s) and how can we best support problem attention/solution given the available AI and conventional decision support technologies.

### 3:1 Research objective

The objective of the research was to develop both a conceptual and operational design for an intelligent system for the purpose of developing and assessing internal controls for the detection and prevention of financial fraud. Figures 1 - 5 show a conceptual diagram for the integrated system and Figure 6 shows the operational components for the integrated system.

Many of the professional pronouncements dealing with internal controls over the past few years have suggested three major areas of emphasis for evaluating and maintaining internal control: (1) control environment, (2) accounting system and (3) control procedures.

The control environment is concerned with management's philosophy and operating style, the entity's organizational structure, the manner in which authority and responsibility is delegated, the function of the board of directors and especially the audit committee of the board, management's control methods for monitoring and following up on performance, personnel polices and practices and various external influences that affect an entity's operations and practices.

The accounting system is concerned with identification, measurement, presentation and timeliness of accounting transactions and events.

The control procedures are those specific procedures implemented to insure safeguarding of assets, provide for proper valuation of assets, provide for proper authorization of transactions and to provide for adequate recording and reconciliation of accounting transactions.

In order to facilitate the research, a number of assumptions were made relative to the control environment, accounting system and control procedures. In particular, to make this project manageable, the scope of this research was on the revenue cycle of a firm.

### 3:2 Scope

The scope of the research is limited to revenue recognition, in particular the falsifying of sales, pre-invoicing and sales cut-off.

### 3:2 Approach

Our approach is based on several questions that relate to fraud detection/prevention and the implications for the system of internal controls. The problem scope (in this case revenue recognition) must drive the analysis for fraud prevention/detection/control environment.

Questions that helped us focus on the relevant areas of interest included: What different approaches can we use to solve or determine the existence of revenue recognition problems? What information is necessary for those approaches? Who would benefit from changes in revenue recognition? How can we address the three components of control: environment, system and procedures simultaneously? How can we make the system dynamic and responsive to change in the environments of the control system? These basic questions and others lead to the development of tests and signals derived from the tests (red flags). These signals are utilized to determine the extent to which the system of internal controls is operating in a satisfactory manner and to facilitate feedback and adjustment measures and methods to "correct" the system of controls if so indicated.

### 3:3 Assumptions

Given the wide latitude of accounting systems in existence in firms and ways in which accounting data is stored and accessed, several simplifying assumptions were made to facilitate development of the prototype system. Among these assumptions were:

- the existence of a relational database equivalent to a set of documents and instances of those documents. This database is identified in Figures 1 - 6 as "conventional database".
- The intelligent/integrated decision support system (IDSS) prototype is based on four types of specific documents: sales invoice, sales returns and credit document, purchase orders, and picking/shipping documents.
- It is further assumed that these particular documents are static and the relevant fields in the document do not change

in content in the course of normal business activities.

Further assumptions include

- a specific industry representation (computer services, tax services),
- data availability from the past five years,
- availability of an actual firm's policy and procedures which were adapted for aspects of the control environment
- and prior years working papers from a CPA audit.
- Additionally, it is assumed that company history files are available and
- that industry history and projections are assessable as are text databases such as Dow Jones, Standard & Poors, etc.

### 3:4 Analysis

Each of the components of Figures 1 through 5 are now described. Figure 1 shows a main module which interacts with 6 additional modules that form the basis of an integrated decision support system (IDSS). The goal of the IDSS is to provide guidance for monitoring, assessing and developing/ modifying a system of internal controls for the detection and prevention of fraud. The 6 modules include Control and Objectives, Qualitative Assessment, Environmental Monitoring, Transaction Monitoring, Case History and Auditing Feedback.

Figure 2 shows the main module which has general control knowledge and general business and economic knowledge and which serves as the control mechanism for the other 6 modules as internal controls are monitored, reviewed, assessed and modified.

Figure 3 shows the control environment modules which include: Control Objectives, Qualitative Assessment, Environmental Monitoring and Auditing Feedback. The Control Objectives module contains general knowledge of management's goals and objectives. This knowledge especially is focused with respect to the cost/benefit risk assessment of the system of internal controls and the goal congruence issues of the system of controls and overall management objectives. The Qualitative Assessment module allows management to objectively evaluate criteria and alternatives that gives rise to a system of internal controls and facilitates an objective assessment of relevant criteria and weights for these criteria in the system of controls. The Environmental Monitoring module allows events that are external to the firm to be monitored and assessed relative to the likelihood of impact on the firm and the firm's control system. Environmental events might include changes in economic policy and interest rates and/or legal rulings regarding mergers and acquisitions which may encourage significant management action and require modification of the internal control system of the firm. The Auditing Feedback module is to provide a knowledge base of prior years audits both by CPA and internal auditors. This knowledge may be in the form of excerpts from management letters, operational audits and other information.

Figure 4 highlights the modules that comprise the Accounting System. These modules include: Qualitative Assessment, Transaction Monitoring, Auditing Feedback and Case History. The Qualitative Assessment and Auditing Feedback modules have been previously described and in the Accounting System context are focused on the details of maintaining an adequate and responsive accounting system. The Transaction Monitoring module monitors transactions and generates indications of weaknesses in the overall accounting system. The Case History module provides histories of prior events both in the firm and in other firms within the same industry in order to provide "analogical bases" for comparison to current events. In other words, this module allows reasoning regarding current events to be placed in context of similar events that may have occurred in the firm of interest in prior years or in other firms within the same industry. In this way, analogical reasoning may be used for control monitoring and adjustment.

Figure 5 focuses on the control procedures. Modules include: Transaction Processing and Auditing Feedback. The transaction monitoring modules is as previously described and in addition allows detailed analysis of transactions both at the document and transaction level. Four different types of activities take place in this module: analytic review, analysis of individual document information, linked multiple documents information and image manipulation, scanning and comparison of key documents. This module looks for patterns in documents and transactions that meet (or depart from) pre-specified control assumptions and requirements. Analysis of a simulated set of documents provides a set of knowledge structures that, when combined with control assumptions and weights provides a normal template against which to measure or compare future transactions. This knowledge structure then provides a feedback mechanism which provides guidance for fine tuning controls and, by implication, provides suggestions for strengthening or assigning more weight or priority to certain sets of controls.

### 3:5 Specific component analysis

Built into our algorithm for assessing transactions is an analytic review procedure that in addition to typical ratio analysis and statistical analysis of account balance relationships looks at multiple-account effects simultaneously.

### 3:6 Single document analysis

This sub-part assumes that each document has a "profile", e.g., Is the document complete; Is there an indication of appropriate or "normal" authorization and so on. Pattern matching techniques through scanning are utilized to "recognize" correct documents.

### 3:7 Multiple document analysis

This component required the transactions to be represented in a relational database. This allows assessment of linked investigation of documents such as "were documents initiated in appropriate date sequence; do quantities correspond; were the same approvals found on multiple linked documents; was there an appropriate source document?

In summary, the analysis generated by the IDSS provides a merger of the traditional, top-down, conceptual view of establishing a control environment and testing to see if the control environment is in place and functioning as expected with a bottoms-up or data driven approach. This bottoms-up approach provides templates or norms based on pattern analysis of fields in documents which then can be set to evaluate future transaction flows for anomalies or deviations. The merger of the top-down and bottoms-up approaches allows dynamic assessment of transactions as they occur which can then trigger "red flags" for audit/management attention directing. In addition, the bottoms-up analysis provides feedback information for re-assessing the weights of the control environment over time. This approach focuses on the problem domain and the types of decisions that are necessary to be supported in this domain. At this point no mention is made of technology, only the problem domains and structure. The merger of the top-down (deductive) and bottoms-up (inductive) approaches are supported by appropriate technology as described in the operational model.

## 4: Operational model

Figure 6 shows the same modules as above but with the operational components highlighted in reverse (white) type face. These operational components include: rules, frames, neural networks, natural language parsers, case based reasoning, genetic algorithms, analytic hierarchy process and an expert systems shell. The expert systems shell provides the basic level of knowledge and serves to integrate the other components together in a "super" IDSS. Note that alternatives could be specified for several of these modules and the resolution of which alternative is most appropriate is often an empirical issue. For example, the integrative module might well be a neural net interfaced with the expert system shell. We are evaluating that proposition and others in a follow-up study. Each component is now briefly described.

### 4:1 Rules

The rules are IF.. Then.. Else and allow conditional statements to be asserted about general and specific control conditions: For example, IF oil prices are rising AND lower consumer demand for goods and services is indicated AND reduced availability of capital is indicated AND the firm is highly leveraged THEN further investigation of these factors effects on the firm is indicated. Another rule example is: IF unauthorized changes can be made to cash receipts transactions AND bank deposits and cash receipts are not independently reconciled THEN a red flag for potential accounts receivable problems is indicated.

The rules are represented in knowledge bases for the main IDSS module and for the auditing feedback and control objectives modules of Figures 1 - 6.

### 4:2 Neural networks

Neural networks are used to scan transactions for patterns and to detects anomalies from the "norm". In addition, the neural networks are trained to read documents such as invoices and to detects anomalies in future documents which are scanned. Four neural network algorithms are used in the current prototype: multi layer backpropogation (MBPN), counterpropogation (CPN), Brain State-in-a-Box (BSB) and Adaptive Resonance Theory 2 (ART2). BSB is used to diagnosis potential problems in transactions provided by an analytical review based on ratios, trends and budgets given a "symptoms - diagnosis" perspective; the diagnosis being a "red flag" or signal situation that might indicate potential problems in the set of transactions. MBPN is used to classify transactions "on the fly" into acceptable or "red flag" conditions. ART2 is used to evaluate images in the form of scanned documents and detect potential difficulties on the document such as absence of appropriate numbers such as purchase orders numbers, absence or problems with appropriate authorizations and so on. CPN is used to evaluate relationships between account balances and the underlying transactions that give rise to these account balances over time. Thus CPN looks at the interdependence relationships between accounts. Neural networks are embedded into the transaction monitoring module in Figures 1 - 6. Note that case-based reasoning methods could also be utilized here but neural nets were deemed to be more appropriate in this particular domain.

### 4:3 Genetic algorithms

Genetic algorithms allow learning and natural selection to take place in neural networks and to facilitate adaptability of the networks to adapt to new situations. Genetic Algorithms are utilized in the Transaction Monitoring Module of Figures 1 - 6 to adapt the networks based on new, significant information.

### 4:4 Analytic hierarchy process

The analytic hierarchy procedure (AHP) is a method for formally and objectively eliciting criteria and alternatives for a given decision setting: in this case internal control system decisions. AHP is not an AI technology but rather a conventional decision support tool which is most appropriate for this particular module. Through use of this process, objective weights can be determined and applied through the model to select alternatives that are optimal, given the preference structure of the individual evaluating the criteria and alternatives. AHP is used in the Qualitative Assessment module of Figures 1 - 6 where decision makers (auditors, management) make "trade-off" decision concerning evaluation, use and implementation of various control procedures.

### 4:5 Natural language parsers

Natural language parsers allow the reading of text databases and making "sense" out of text items and stories that may impact the control system. Natural language parsers are found in the Environmental Monitoring module of Figures 1 - 6 where they are utilized to scan text databases (external to the firm) for key phrases that might have implications for the control system of the firm. Such key phrases may have to do with directors' securities transactions or merger-acquisition activity.

### 4:6 Case based reasoning

Case based reasoning is a technique that allowing indexing of past experiences and facilitating the use of these past experiences in considering current events. Case based reasoning is utilized in the Case History module of Figures 1 - 6 and is used to organize prior events within and outside the firm that might be useful for consideration in context of current problems. Cases are simply groups of features such as information concerning prior acquisitions that can be used in current decision situations.

### 4:7 Frames

Frames are means of organizing knowledge into conceptual hierarchies in which lower level concepts inherit properties of higher level concepts. Frames are also utilized in the Case History module and in the Main module of Figures 1 - 6. Frames provide a somewhat "richer" knowledge representation mechanism than rules and enhance the capability of the modules where conceptual relationships are more dominant the procedural relationships.

### 4:8 Expert systems shell

The expert system shell is a computer program which incorporates an inference mechanism with knowledge bases in the form of rules and frames and facilitates integration of other tools such as neural networks and other programs such as AHP. The expert systems shell used for this prototype has the ability to display both text and graphical interfaces, generate written reports, provide a documented trace of the decision analysis (for future reference, audit and documentation), and provide a variety of inference capabilities. Of particular interest is the ability to have "fuzzy" representation of inference in the rule based component of the prototype. Fuzzy representation is based on numerical representation of structured knowledge which is represented as a continuum rather than discrete events such as probabilities and certainty factors which dominate many expert systems products. Although not accomplished at this point in the research, a neural net may also be used to integrate the diverse modules together and when coupled with the expert system, provide superior management of the IDSS.

## 5: Discussion

The IDSS applies the most appropriate AI and non-AI technologies to the overall problem: internal control monitoring and maintenance from a fraud detection/prevention perspective. Transactions which tend to be high in volume are monitored by data intensive AI technologies: neural nets, genetic algorithms and case-based reasoning. Qualitative assessments of criteria are most appropriately handled with multi-criteria decision modeling represented by the AHP. Other modules are more concept oriented and thus frame and object hierarchies make sense for knowledge representation in these sub-areas. Still other sub-systems are more rule-like and thus rule based systems are appropriate. Natural language is useful for scanning text sources of information to provide "red flag" indicators as appropriate. The overall integration and management of these sub-systems or modules is handled by an expert system interfaced with a neural net. The expert system has fuzzy logic which allows greater flexibility and more power with fewer rules than a conventional ES.

Decision Support Systems are concerned with the database(s), models base and user interface. In this prototype system, the interface has hypermedia and multimedia qualities with the embedded AI components. The databases are part of the overall IDSS and specific attention may be directed to the appropriate interface between the database query language (SQL) and the neural net. At this point in the research, the interface is contrived to provide proof of concept of the AI integration. Model-based reasoning, although not specifically addressed in this study, can be integrated into this system. For example, a model of audit risk with attendant knowledge structures may be useful as a risk assessment tool to integrated with the other elements of this system.

The contribution of this research is the notion of a multimethod, portfolio approach to building intelligent decision support systems. The issue is not an either or situation.

Rather it is a how best situation. That is, how best can we solve or address a particular problem with the portfolio of AI and conventional DSS tools available. The integration of this tools can be challenging but the rewards of increased power and flexibility are potentially great.

## References


[1] Bell, T. "Neural Nets and Logistic Regression in Auditing", working paper, KPMG Peat Marwick, 1989.

[2] Meservy, R. "Case Based Reasoning and Neural Nets", working paper, 1991.

[3] Meservy, R., Hansen, J. and E. Denna., "Cased-based Reasoning and Bankruptcy Prediction", working paper, 1991.

[4] Mott, S. "Case-based Reasoning for Telex Support", FAIM Proceedings, US Department of Defense, 1990.

[5] Pinson, S., "Logit Models versus Neural Nets for Financial Analysis", forthcoming Intelligent Journal for Systems in Finance, Accounting and Management, 1992.

[6] Turban E., and Watkins P.,"Integrating Expert Systems and Decision Support Systems", MIS Quarterly, June 1986.

[7] Turban E., "Comparison of Expert Systems and Neural Nets", working paper, California State University, Long Beach, 1991.

[8] Watkins, P.R. and O'Leary, D.E. "A Views Model for Intelligent Systems Integration", working paper, ATISP, 1989.

[9] Watkins, P.R. and O'Leary D.E., "Integration of Intelligent Technologies into Conventional Information Systems: Key Issues, Opportunities and Potential Pitfalls," Expert Systems in Finance, John Wiley & Sons, LTD., 1991.


**Figure 1: Conceptual Diagrram for an Integrated Guidance Decision Support System to Assist in Developing and Assessing Internal Controls**

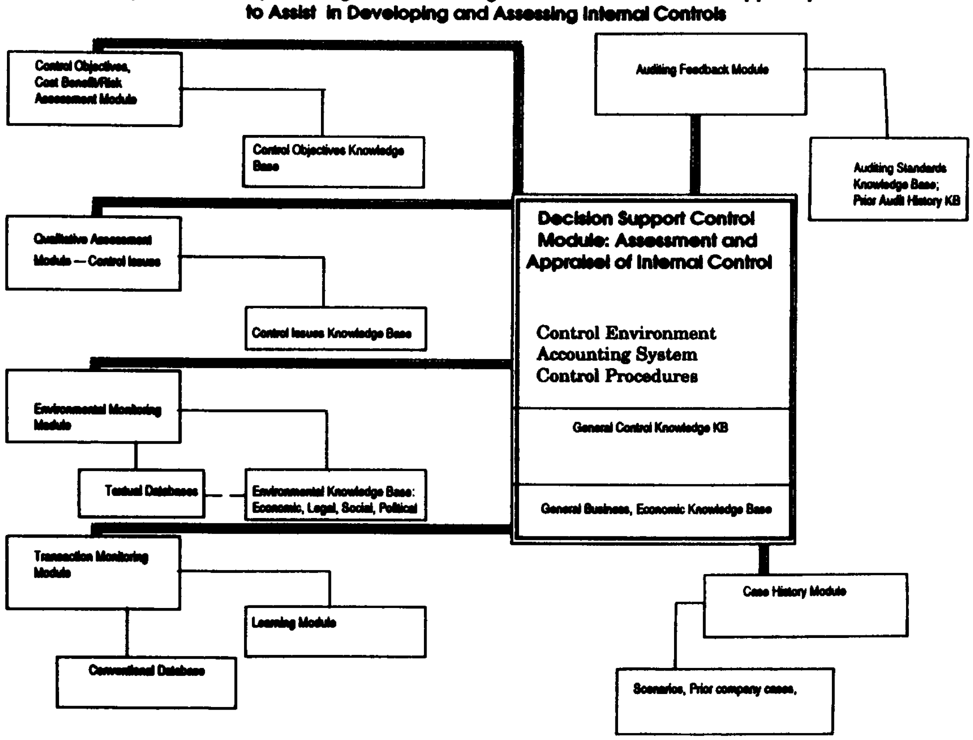

**Figure 2: Main Module for an Integrated Guidance Decision Support System to Assist in Developing and Assessing Internal Controls**

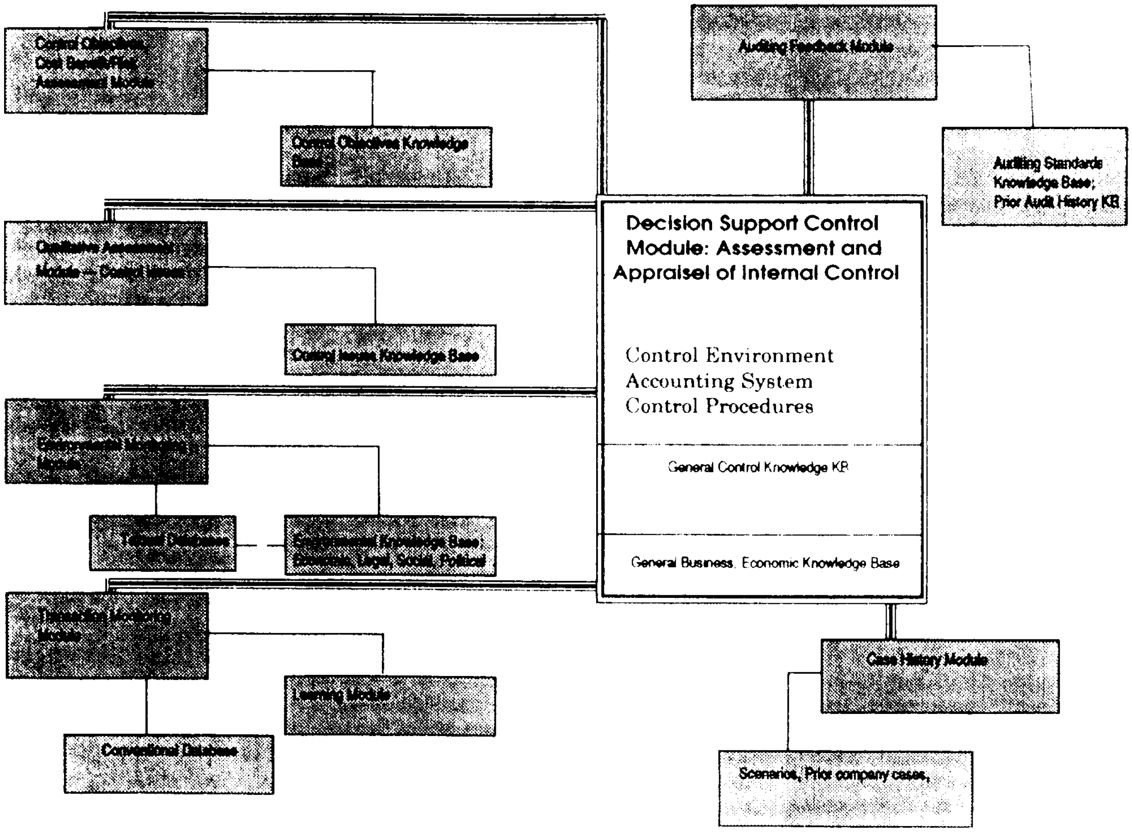

**Figure 3: Control Environment Sub-Modules for an Integrated Guidance Decision Support System to Assist in Developing and Assessing Internal Controls**

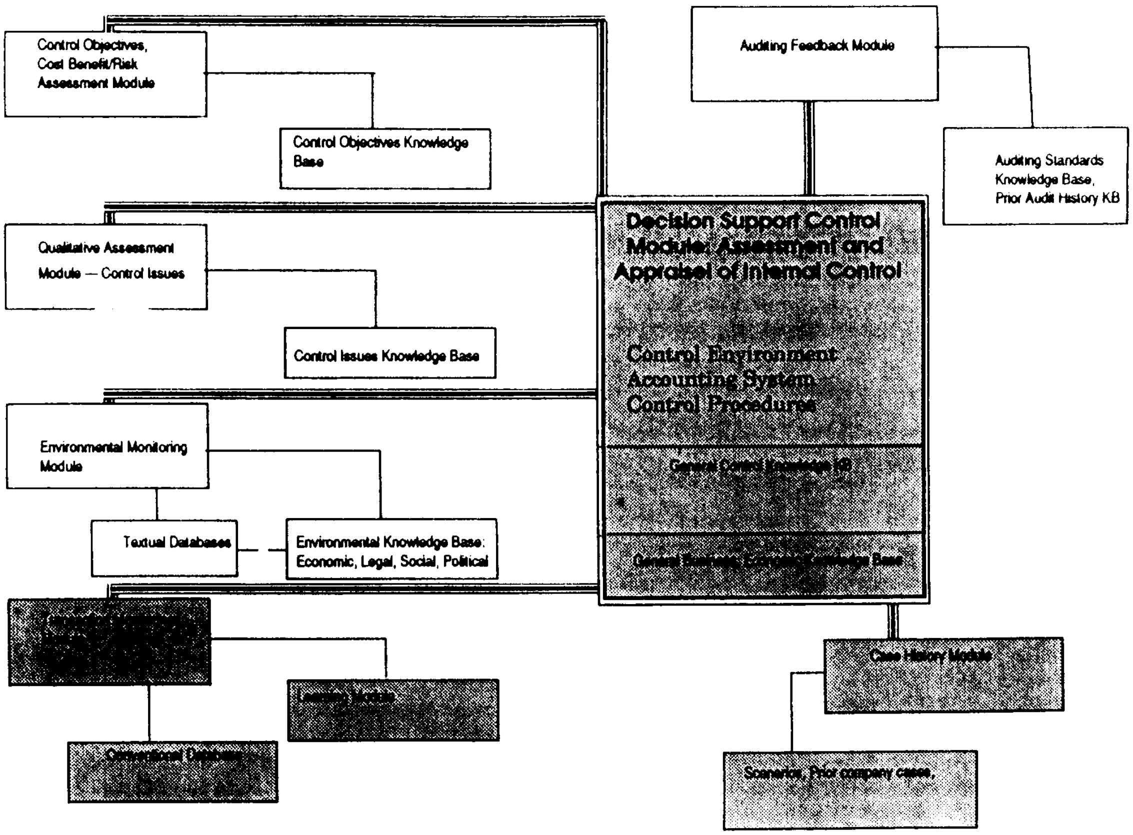

**Figure 4: Accounting System Sub-Modules for an Integrated Guidance Decision Support System to Assist in Developing and Assessing Internal Controls**

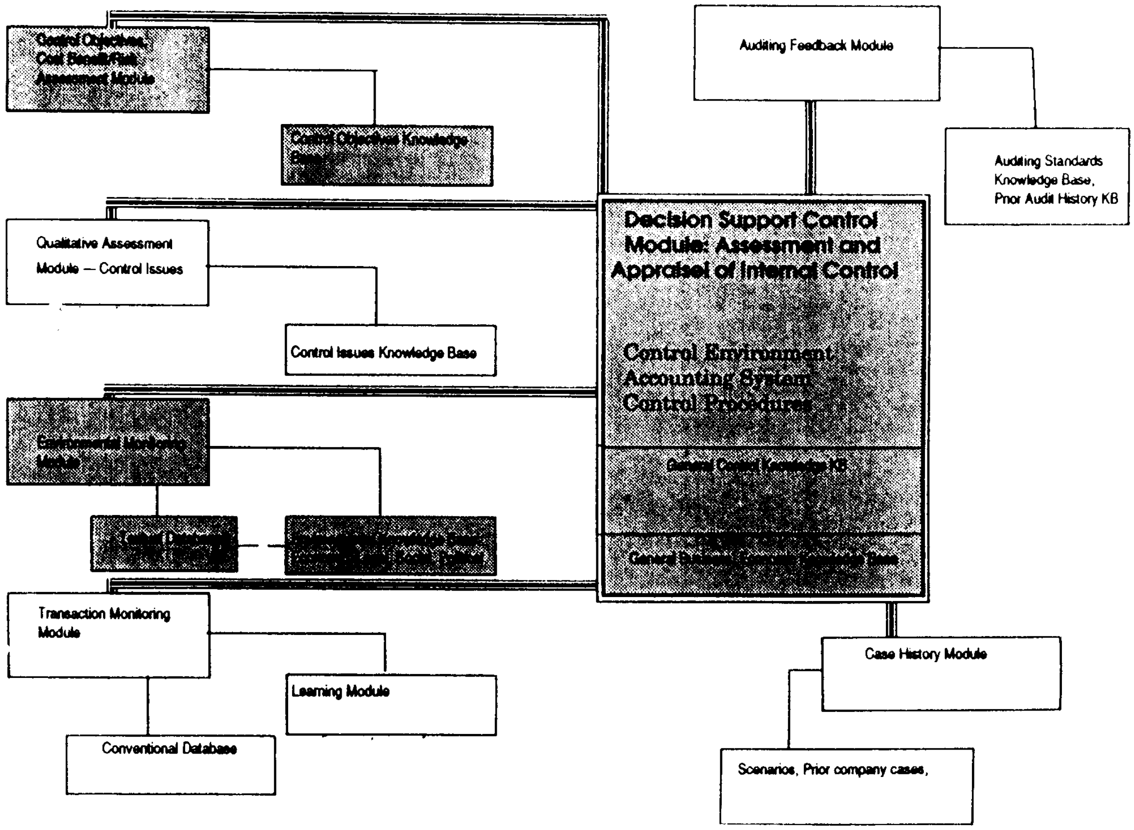

**Figure 5: Control Procedures Sub-Modules for an Integrated Guidance Decision Support System to Assist in Developing and Assessing Internal Controls**

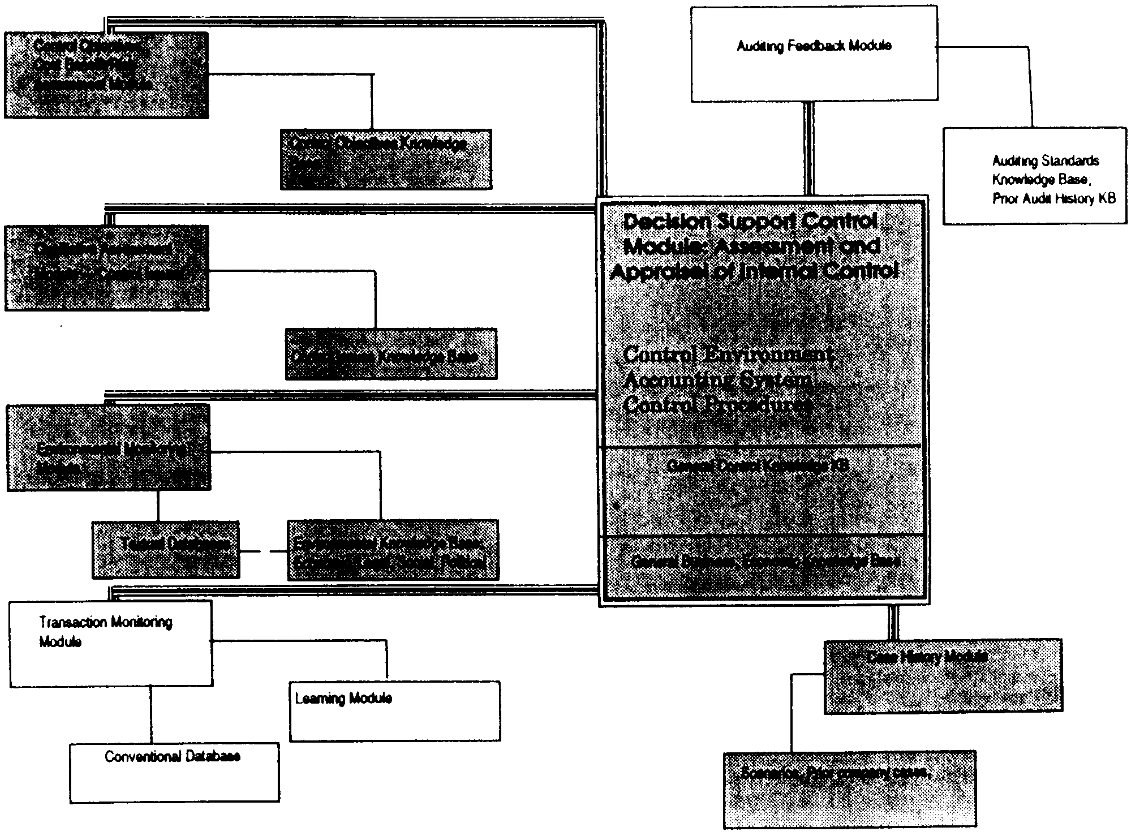

Figure 6: Operational Technologies for an Integrated Guidance Decision Support System to Assist in Developing and Assessing Internal Controls