An Accounting Prototype Expert System

DANIEL E. O'LEARY, and TOSHINORI MUNAKATA

Introduction

For the past decade or so, extensive work has occurred in knowledge-based expert systems. More recently, accounting researchers have focused on developing knowledge-based expert systems for accounting problems. This paper discusses a system for use in developing aggregated financial statements in the design of an accounting information system. AGGREGATE develops *aggregated* financial statements to be used in accounting information systems (AISs). For example, AGGREGATE would use as input Table I and produce Table II as output. AGGREGATE is designed to simulate the approach of a human accountant designing financial statements for an AIS by using heuristics and other rules of thumb in the computer program in order to accomplish that task.

AGGREGATE was developed using the computer language PROLOG. AGGREGATE uses a frame-based knowledge representation with an inference engine that is a combination of forward chaining and backward chaining designed to solve the specific problem.

Artificial Intelligence and Expert Systems

Artificial Intelligence (AI) is that part of computer science aimed at developing computer programs that perform tasks

TABLE I

An Input Example—Financial Statement Before Aggregation

BOSTON EDISON COMPANY—DECEMBER 1963

	Dollars	*Transactions*
Cash	$ 4,048,773	167,354
Special-Deposits	1,166	87
Working-Funds	242,495	608,959
Notes Receivable	53,004	911
Customers' Accounts Receivable	17,448,883	17,392,927
Other Accounts Receivable	479,353	74,945
Fuel Stock	1,218,478	75
Plant Materials, Supplies, and Merchandise	7,176,643	8,056
Prepaid Insurance	369,210	894
Other Prepaid Items	10,028	742
Rents Receivable	40,607	962
Miscellaneous Current and Accrued Assets	61,032	1,480
Net Electric Plant In-Service	327,802,559	109
Electric Plant Construction-In-Progress	21,609,430	723
Net Steam Plant In-Service	10,520,537	15
Steam Plant Construction-In-Progress	179,584	76
Net Nonutility Property	2,167,063	201
Other Investments	1,758,042	1,358
Unamortized-Discount Series-D Bonds	41,501	80
Refunding-Costs Series-G Bonds	341,875	120
Temporary-Facilities	18,249	1,040
Deferred-Debits Federal-Income Tax	990,800	89
Deferred-Debits Miscellaneous	321,644	1,655
Nonutility Property Additions	82,193	842
Deferred-Debits Sewer-Use Tax	12,037	895

This example is constructed by the authors for illustration purposes from information given in Lev (11). For example, the order of the items is rearranged and the number of transactions is added.

requiring intelligence and which, for the moment, humans are more capable of doing (Barr and Feigenbaum, 1982; Rich, 1983). Expert Systems (ESs) are a branch of AI. ESs are computer programs that can perform a task in a specific task domain as well as a human expert can perform the same task (Barr and Feigenbaum, 1982; Davis and Lenat, 1982; Hayes-Roth et al., 1983).

ACCOUNTING EXPERT SYSTEMS

There are a number of accounting expert systems (AESs) that have been developed for commercial use. Peat Marwick Main &

TABLE II

Final Output of the System—An Aggregated Internal Accounting Statement for Table 1 Input.

Category No.	*Original No.*	*Title*	*Dollars*	*Transactions*
1	1	Cash	$ 4,048,773	167,354
1	2,3	Special-Deposits and Working-Funds	243,661	609,046
1	4,5	Prepaid Insurance and Other Prepaid Items	379,238	1,636
1	6,7,8,9	Receivables	18,021,847	17,469,745
1	10,11	Fuel Stock and Plant Materials, Supplies, and Merchandise	8,395,121	8,131
1	12	Miscellaneous Current and Accrued Assets	61,032	1,480
2	13,14	Other Investments and Temporary-Facilities	1,776,291	2,398
2	15	Net Electric Plant In-Service	327,802,559	109
2	16	Electric Plant Construction-In-Progress	21,609,430	723
2	17,18	Net Steam Plant In-Service and Steam Plant Construction-In-Progress	10,700,121	91
2	19,20	Net Nonutility Property and Nonutility Property Additions	2,249,256	1,043
3	21,22	Unamortized Discount Series-D Bonds and Refunding-Cost Series-G Bonds	383,376	200
3	23,25	Deferred-Debits Federal Income Tax and Deferred-Debits Sewer-Use Tax	1,002,837	984
3	24	Deferred-Debits Miscellaneous	321,644	1,655

Co. is currently testing an AES to analyze bank loans (Willingham and Wright, 1984). Coopers & Lybrand has implemented a system for tax accrual planning (Shpilberg and Graham 1986a and 1986b). Other AESs include prototype systems, such as the AES developed in this paper, e.g., TAXADVISOR (Michaelsen, 1984), AUDITOR (Dungan and Chandler 1985), EDP AUDITOR (Hansen and Messier, 1982 and 1986), and ICES (Grudnitski, 1986).

TAXADVISOR, an AES designed for use in estate planning, was developed using EMYCIN. AUDITOR, designed for auditing the allowance for bad debts account, was developed using AL/X. EDP AUDITOR, an AES designed for use in auditing EDP systems, was developed using AL/X. ICES, designed to facilitate the elicitation of knowledge from an auditor about the internal control environment, was developed using EMYCIN.

AES prototypes provide a useful tool in accounting research and in accounting practice. Accounting research uses AES prototypes to determine the feasibility of developing an AES in a specific area, to understand the judgments and heuristics used in a specific decision and as an aid in understanding a specific judgmental area: if you can't program a decision-making process, it is likely that it is not understood. Accounting practice can use AES to supplement or replace decision makers.

Aggregation of Accounts in AIS

Aggregation of accounts in internal financial accounting reports is a practical problem faced by the accounting information systems designers, even though managers theoretically can use their firm's accounting database to ascertain the information required to meet their needs. However, for a variety of reasons financial reports are prepared for managers, thus eliminating the need for them to analyze the database directly. These reasons include the need to:

(1) develop accounting information systems that provide decision makers with the information necessary to make good decisions

(2) design information systems that are cost-beneficial

(3) develop responsibility-based accounting information systems and

(4) meet security requirements.

First, sometimes it is thought that the decision maker should be provided with all available information. However, in Ackoff's classic paper (1967), it was noted this can lead to an overabundance of irrelevant information. The level of aggregation can affect the quality of the decisions made by a manager (White, 1983). This suggests that there is some "appropriate" level of aggregation that is somewhere between "all the available information" and "too much" aggregation.

Second, information systems should be cost-beneficial. The negative impact of information availability of aggregation should be offset by other factors. Although aggregation can decrease the quality of decisions, it is not necessarily cost-beneficial to present decision makers with a highly unaggregated set of accounts. This occurs for two primary reasons. First, the decision-making time increases as the amount of aggregation decreases (White, 1983). Too much time spent on one decision can lead to a sacrifice in the quality of another decision. The use of aggregation provides a trade-off between the amount of time spent on each of a portfolio of decisions. Second, the cost of maintaining an unaggregated system is larger than the cost of a more aggregated system. For example, a larger number of accounts means more coding errors on the entry of information into the system and larger resource requirements for maintenance of the system.

Accounting information systems usually are responsibility-accounting systems. Such an accounting system assigns responsibility to a manager for organizational performance and provides the manager with a series of accounting reports that summarizes the relevant information necessary to manage. For example, the president of a company is not responsible directly for the dollars spent on paper clips, so a financial statement for the president would not directly include that account. However, the president may be responsible for the total supplies expenditures for the firm via a profit figure. Consequently, all the individual accounts that go into supplies would be aggregated for the president's report.

An accounting system also has a number of accounts that have security and other considerations. These accounts must be aggregated to ensure that the contents are not discovered by the general population of the firm. For example, accounts that relate

to firm strategies or executive salaries are not of concern to all firm members. These accounts must be aggregated to camouflage underlying critical information.

THEORETIC CONSTRUCTS AND EMPIRICAL FINDINGS

There has been limited theoretical and empirical work in the aggregation problem in AIS. Lev (1969) used entropy or "information theory" to analyze the aggregation problem in AIS. He maximized the information content in the reports provided to management. Information theory was used to measure the information content. However, that approach has been criticized for a number of reasons (e.g., Feltham, 1972 and Ronen and Falk, 1973).

ACTUAL APPROACHES TO AGGREGATION IN AIS

Since there is no generally accepted framework for the aggregation of financial statement information, designers of AIS generally use multiple sources of knowledge to develop aggregated financial statements:

1. Theoretical/Empirical Findings
2. Design Heuristics
3. User Requirements
4. Materiality Requirements

The limited theoretical and empirical work on aggregation in internal financial statements has suggested some judgmental heuristics. For example, Lev's (1969) entropy-based analysis suggested aggregating accounts whose dollar balances are a small percentage of the total dollar balance of the set of accounts.

Design heuristics derive from the apprenticeship nature of the development of AIS that occurs in accounting firms and from the subsequent design of AIS. One of the authors has previously worked in developing AISs and some of his experience has been built into AGGREGATE.

User requirements help define the level of aggregation of accounts on financial statements. For example, as noted above,

the president does not need to know supply expenditures, yet he or she may find that executive salaries is a critical account.

Materiality requirements suggest that the dollar balance in the accounts affects the aggregation of accounts. For example, a materiality level typically of 5% of a given standard quantity is used by accountants.

IMPLEMENTATION OF THE AGGREGATION OF FINANCIAL STATEMENTS

AGGREGATE uses three basic steps to develop aggregated financial statements:

1. Determining the accounts that should be aggregated
2. Identifying the sets of accounts that can be aggregated with each other and
3. Choosing between alternative sets of potential account aggregations.

Determining the accounts that should be aggregated involves identifying those accounts that for some reason (e.g., lack of importance or for security reasons) should be aggregated with other accounts. Identifying the accounts that can be aggregated is the process of determining which accounts are somewhat similar so that it makes "sense" to aggregate those sets of accounts. Choosing between alternative sets of potential aggregations is the process of meeting the constraints that have been identified while providing decision makers with the necessary decision-making information.

Determining The Accounts That Should Be Aggregated

To provide management with a financial statement that allows it to focus on important decision-making variables, the financial reports they receive should reflect the "important" accounts. Those unimportant accounts can be aggregated with other accounts to develop an aggregated financial statement. The development of AGGREGATE lead to the recognition of three sources of information on which to base the decision to aggregate or not aggregate an account:

1. Activity Level
2. User Requirements
3. Security Requirements

ACTIVITY LEVEL

Activity levels of an account provides a measure of the importance of the account to a decision maker. Human accountants routinely use two measures to determine the activity level of an account: the dollar amount of the account and the number of transactions of the account.

AGGREGATE also uses these same measures of activity levels. If both of these measures are below a certain level, then AGGREGATE indicates that those accounts should be aggregated. AGGREGATE uses heuristic-based percentages of the total dollar volume and the total number of transactions. In addition, the totals are based on the category totals of the type of assets—for example, current assets. AGGREGATE uses materiality percentages of the category totals.

USER REQUIREMENTS

Human accountants also determine unique user requirements. This is particularly important in cases where accounts are determined to be insignificant (as above), but the user regards them as important. Typically, each firm has a set of expenses that it may consider important but other firms may not. Alternatively, an account may show as important in the above analysis but it may not be important to the particular manager. AGGREGATE can be extended to accommodate these requirements.

SECURITY REQUIREMENTS

A third approach used by accountants is to determine if there are any potential security leaks in the disclosure of particular accounts. For example, executive salary expenditures may be an appropriate account for just a select set of personnel—possibly only the president. Since AGGREGATE is only a prototype, this is not yet a major concern.

Identifying Sets Of Accounts That Can Be Aggregated

Next, the human accountant must determine which accounts make "sense" to aggregate with the accounts that have been determined to require aggregation. For example, in Table I, the human accountant would likely decide that it makes "sense" to aggregate the first three items, "Cash," "Special-Deposits," and "Working-Funds," while the accountant would decide that it may not make "sense" to aggregate "Cash" and "Net Electric Plant In-Service." What knowledge does the accountant use to make such a decision?

ACCOUNTING LANGUAGE PROCESSING

The accountant has a vocabulary of accounting words that describe the accounts. These accounting words have implicit characteristics associated with them. Two primary characteristics are time frame and liquidity. For example, "Cash" is a short-term and highly liquid asset, whereas, "Net Electric Plant In-Service," is a long-term asset with very little liquidity. Because those characteristics are different it may not make "sense" to aggregate those particular assets.

Concepts of a "vocabulary of accounting words" and "characteristics" suggest *natural language processing* used in AI (e.g., Reitman, 1984). We could employ some of the techniques developed for natural language processing. An alternative, however, is to develop an approach that meets the specific needs of our problem domain.

ACCOUNTING VOCABULARY REPRESENTATION IN AGGREGATE

Accounting vocabulary representation in AGGREGATE is implemented as follows. First, given an account title, the "importance level" (called the *hierarchical level*) of each word is determined. Level 1 is treated as the most important and Level 8, the least important—for example, "Net (Level 6), Electric (Level 4), Plant (Level 1), and In-Service (Level 2)." Such hierarchical levels are assigned to the words so the significance of the words in determining the characteristics of the account title are not

equal. That is, in each title there is a "key word" and less important words. To determine the characteristics of an account title, the key word must be found.

AGGREGATE uses the hierarchical levels found in a table referred to as "Hierarchical Levels of Accounting Words" (see Table III). This table, in the form of a list, is given to AGGREGATE as a priori knowledge.

Not every word in the table has a unique level. For example, the word "Plant" in "Net Electric Plant In-Service" is a key word, i.e., Level 1. However, the "Plant" in "Plant Materials, Supplies, and Merchandise" is not a key word, but instead is a Level 5 word. The latter is identified by the fact that there is another Level 1 word in the title.

This table is not the only table that could be constructed to represent accounting language. Because this table was designed to meet the needs of this application, it reflects the asset side of the balance sheet, general accounting knowledge, and selected industry knowledge required for this application.

Levels were designed to group conceptually similar accounting words that the system would encounter. Level 1 includes the set of key words that AGGREGATE recognizes. Level 2 summarizes the state of plant assets. Level 3 defines the descriptors associated with receivables. Level 4 reflects the industry-specific descriptors. Level 5 includes the set of descriptors that are not key words, but are the same as key words (e.g., Plant Asset as opposed to Plant Supplies). Level 6 summarizes the descriptors deriving from the depreciation or amortization of assets. Level 7 includes the miscellaneous asset descriptors. Levels 5, 6, and 7 words generally are not required to derive the "meaning" of the particular accounting descriptor.

Given that AGGREGATE has found the Level 1 word in a given title, it uses that Level 1 word to determine the characteristics associated with the title. The characteristics provide the "meaning." The characteristics are based on the two dimensions of time frame and liquidity. These dimensions are typically used by accountants to develop financial statements. Generally, the time frame determines the category in which the asset is included (e.g., current or long-term). In addition, the liquidity determines the order of appearance within a category. Table IV shows the set of characteristics for time frame and Table V shows the characteristics for liquidity. Table VI shows the assets in Table I sorted according to those categories.

Table III. Hierarchy Levels of Accounting (Level 1 is the highest)

Level 1

plant,* property, investments, equipment, cash, special-deposits, working-funds, receivables, stock, supplies, merchandise, materials, prepaid, current, accrued, unamortized discount refunding-cost, temporary-facilities, deferred-debits, inventory

Level 2

In-service, in-progress

Level 3

notes, accounts, rent, bonds

Level 4

Electric, steam, fuel, nonutility, construction customers, insurance, series-D, series-G, tax

Level 5

plant* (if there are no other components that are Level 1)

Level 6

net

Level 7

other, items, additions, miscellaneous, assets

Level 8

(all other words that do not appear in Levels 1 through 7)

*Note: "plant" is in Levels 1 and 5.

Table IV. Vocabulary set of accounting words for time frame

A1. Current (short term)
cash, special-deposits, working-funds, receivable, stock, supplies, merchandise, materials, prepaid, current, accrued, inventory

A2. Long term
investments, plant, property, equipment, temporary-facilities

A3. Deferrals
unamortized-discount, deferred-debits, refunding costs

Table V. Vocabulary set of accounting words for liquidity

B1. cash, special-deposits, working funds
B2. investments
B3. prepaid
B4. receivable
B5. merchandise, inventory
B6. supplies, stock, materials
B7. current, accrued
B8. temporary-facilities
B9. equipment
B10. plant
B11. property
B12. deferred-debits, refunding-costs, unamortized discount

TABLE VI

The input items are classified into three categories and rearranged based on their characteristics; their category and serial numbers are also assigned.

Category (A No.)	*B No.*	*Serial No.*	*Title*	*Dollars*	*Transaction*
1	1	1	Cash	$ 4,048,773	167,354
1	1	2	Special-Deposits	1,166	87
1	1	3	Working-Funds	242,495	608,959
1	3	4	Prepaid Insurance	369,210	894
1	3	5	Other Prepaid Items	10,028	742
1	4	6	Notes Receivable	53,004	911
1	4	7	Customers' Accounts Receivable	17,448,883	17,392,927
1	4	8	Other Accounts Receivable	479,353	74,945
1	4	9	Rents Receivable	40,607	962
1	6	10	Fuel Stock	1,218,478	75
1	6	11	Plant Materials, Supplies, and Merchandise	7,176,643	8,056
1	7	12	Miscellaneous Current and Accrued Assets	61,032	1,480
2	2	13	Other Investments	1,758,042	1,358
2	8	14	Temporary-Facilities	18,249	1,040
2	10	15	Net Electrical Plant In-Service	327,802,559	109
2	10	16	Electric Plant Construction-In-Progress	21,609,430	723
2	10	17	Net Steam Plant In-Service	10,520,537	15
2	10	18	Steam Plant Construction-In-Progress	179,584	76
2	11	19	Net Nonutility Property	2,167,063	201
2	11	20	Nonutility Property Additions	82,193	842
3	12	21	Unamortized Discount Series-D Bonds	41,501	80
3	12	22	Refunding-Cost Series-G Bonds	341,875	120
3	12	23	Deferred-Debits Federal Income Tax	990,800	89
3	12	24	Deferred-Debits Miscellaneous	321,644	1,655
3	12	25	Deferred-Debits Sewer-Use Tax	12,037	895

TABLE VII
Selected Asset Characteristics

A) Time Frame:	1. Current assets (short) 2. long-term investments 3. deferrals
B) Liquidity:	(see Table V)
C) Depreciation:	1. nondepreciated (land, cash) 2. amortize (patent royalties) 3. depreciated (buildings, machines)
D) Use:	1. in operations 2. not used in operations 3. in progress (being built)
E) Cost:	1. historical 2. tied to market value 3. valuation method
F) Commodity: (cash)	1. yes (gold) 2. no
G) Physical Existence:	1. yes (land, building, cash) 2. no (deferral)
H) Source: (n/r / a/r) (not receivable, acct. receivable)	1. customers 2. affiliated companies 3. other
I) Asset Type:	1. ordinary asset 2. contra asset 3. deferral 4. claims

TABLE VIII
The Accounts to Be Aggregated

Category No.	*Serial No.*	*Title*	*Dollars*	*Transactions*
1	2	Special-Deposits	$ 1,166	87
1	4	Prepaid Insurance	369,210	894
1	5	Other Prepaid Assets	10,028	742
1	6	Notes Receivable	53,004	911
1	8	Other Accounts Receivable	479,353	74,945
1	9	Rents Receivable	40,607	962
1	10	Fuel Stock	1,218,478	75
1	12	Miscellaneous Current and Accrued Assets	61,032	1,480
2	13	Other Investments	1,758,042	1,358
2	14	Temporary-Facilities	18,249	1,040
2	18	Steam Plant Construction-In-Progress	179,584	76
2	19	Net Nonutility Property	2,167,063	201
2	20	Nonutility Property Additions	82,193	842
3	21	Unamortized Discount Series-D Bonds	41,501	80
3	25	Deferred-Debits Sewer-Use Tax	12,037	895

TABLE IX
The Set of Potential Tuples for Aggregation

The elements in the tuples are Serial Numbers in Table VII.

(1, 2, 3)	(1, 2)	(1, 3)	(2, 3)
(4, 5)	(6, 7, 8, 9)	(7, 8)	(10, 11)
(15, 16, 17, 18)	(15, 16) (15, 17)	(16, 18)	(17, 18)
(19, 20)	(21, 22, 23, 24, 25)	(21, 22)	(23, 25)

TABLE X

A Priority Queue Showing the Order of Procedures for the Tuples

*** indicates an item to be aggregated.**

Tuple	*Aggregation Density*	*Cardinality*	*Distance*
(12*)	1.00	1	0
(4*, 5*)	1.00	2	359,182
(13*, 14*)	1.00	2	1,739,793
19*, 20*)	1.00	2	2,084,870
(6*, 7, 8*, 9*)	0.75	4	17,408,276
(2*, 3)	0.50	2	241,329
(21*, 22)	0.50	2	300,374
(23, 25*)	0.50	2	978,763
(1, 2*)	0.50	2	4,047,607
(10*, 11)	0.50	2	5,958,165
(17, 18*)	0.50	2	10,340,953
(7, 8*)	0.50	2	16,969,530
(16, 18*)	0.50	2	21,429,846
(21*, 22, 23, 24, 25*)	0.40	5	978,763
(1, 2*, 3)	0.33	3	4,047,607
(15, 16, 17, 18*)	0.25	4	327,622,975

DEVELOPMENT OF POTENTIAL AGGREGATION TUPLES

To develop the potential aggregation sets (tuples), the human accountant would use the accounts that require aggregation and look for other accounts that makes sense to aggregate with them. First, accounts with the same A (Table IV) and B (Table V) numbers are grouped together as "original tuples." For example, in Table VIII, assets 15, 16, 17, and 18 constitute an original tuple since they have the same A number 2 and B number 10. These tuples represent one type of potential aggregation of accounts: the set of accounts that have the same time frame and liquidity.

Second, another type of potential aggregation is derived from the original tuples by considering their subsets. If a subset contains at least one Level 2, 3, or 4 word in common, then the subset is a potential aggregate; otherwise, it is not considered for aggregation. For example, the subset (15, 16) is a potential aggregation tuple since both accounts 15 and 16 contain a common Level 4 word "Electric." Subset (15, 16, 17) is not a potential aggregate since there is no common Level 2, 3, or 4 word for all the accounts. Table IX shows the set of potential aggregation tuples for the example.

This second process derives its rationale from using additional information in the development of a potential aggregation tuples—it allows the grouping of more closely related sets of assets. In addition, this process is frequently used in the development of aggregated financial statements.

Choosing Between Alternative Aggregations

Given the set of potential aggregation tuples, the AIS system designer must choose between the available alternative aggregations. AGGREGATE uses two heuristic rules to guide the search: (1) minimize the number of accounts that are aggregated, subject to the constraint of aggregating the appropriate accounts (based on the entropy approach of Lev (1969)), that is, choose those sets for aggregation that include more rather than fewer accounts that require aggregation as measured by the aggregation density; and (2) group together similar sized accounts, that is, those with a similar cardinality. This rule is based on practical experience and an analysis of the entropy approach. AGGREGATE uses a heuristic based on these two rules. The results of this approach on the example are summarized in Table X.

Summary

This paper describes an accounting-based prototype expert system that is designed to take as input a set of accounts and characteristics of those accounts (e.g., dollar balances) and develop aggregated financial statements that meet the needs of decision makers. Such statements are provided to decision makers because it is not necessarily cost-beneficial to provide the decision maker with all the information in planning and control systems that make use of responsibility-accounting systems. It is also necessary to meet certain security requirements.

The system first identifies those accounts that need aggregation. Then the system determines which accounts it makes "sense" to aggregate. Finally, the system chooses which aggregations meet certain criteria.

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