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Subject Hierarchy Structure Modeling in Data Warehouse

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Abstract

Data warehouse is subject-oriented organized. However, when data warehousing, the hierarchy structure of subject is currently only decided by decision makers' intuition. Faced with complicated business data mining cases, it is hard to establish hierarchy structure of subject just according to intuition. Thus a method based on ISM is present to make subject level structure establishment more measurable and illustrative. In this article, the "Subject" level structure establishment process is presented firstly. Then the method is put forward. Finally, the rationality and validity of this method are verified by a case on university financial data warehouse's subject level establishment.

Keywords *data warehouse • subject level structure • ISM*

1. Introduction

In data warehouse, data need to be organized and stored according to subject, such as customer, supplier, product, and sales. Rather than concentrating on the day-to-day operations and transaction processing of an organization, a data warehouse focuses on the modeling and analysis of subject-oriented data. In this way, data warehouses typically provide a straightforward and concise view about particular subject issues by excluding data that are not useful in the decision support process. However, currently, subjects are determined by decision makers' intuition. When facing a highly complicated subject system, decision makers are hard to offer a clear and organized level structure of subject in data warehouse just only by their experience.

Interpretative Structural Modeling is defined as a process focused on assisting the human being to comprehend better about what he/she believes and to recognize clearly what he/she does not know [1]. It helps to impose order and direction on the complexity of relationships among various elements of complex system [2]. ISM describes the structure of the system, which describes the relationship between each part and them with the external environment. The so-called relationship includes causality, order, contact relations, and subordinate relations, etc. It is briefness for it just despites the relationship, not involving the size of the quantity. It transits from the concept model of system to the intermediary of quantitative analysis. What most amazing is that it can establish the structure model for systems those hard to quantify. Hence, it is widely used in system analysis and system integrated.

In this paper, the subject level partition algorithm based on Interpretative Structural Modeling (ISM) is proposed to transform unclear and poorly articulated mental models of system into visible and well-defined subject level structure.

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2. Establish Subject Level Structure Based on ISM

2.1 Principle of ISM Method

Interpretative Structural Modeling (ISM) is a kind of method proposed by J. Warfield for analysis of complex social and economic system in 1973 in USA. ISM is a methodology that aids at identifying a structure within a system [3]. It helps to impose order and direction on the complexity of relationships among various elements of a system [4]. For many tangle problems under consideration, an amount of factors might be related to a problem. However, the situation described by the direct and indirect relationships among the factors is far more accurately than the just isolate factor. Hence, ISM contributes to the insights into collective understanding of these relationships.

ISM is wildly used not only at abstraction level but also at concrete level, such as process design, strategic planning, engineering problems, product design, complex technical problems, economic development, traffic accidents, financial decision making, competitive analysis, human resources and electronic commerce [5-8]. In addition, ISM is used in improving group decision-making and knowledge management [9-11].

In ISM technique, a set of different directly and indirectly related elements are structured into a comprehensive systematic model [12]. The basic idea of ISM method is using directed graph or matrix to describe the relationship among the various known elements of the system, then compute and derive based on the matrix, eventually classify disordered elements of system into multi-level system.

2.2 Establish Subject Level Structure Based on ISM

3. Establish University Financial Subject Level Structure Based on ISM

University financial management system provides Ministry of Education with a strong support in daily management of financial decision-making. It is convenient to do all kinds of data aggregation and financial analysis through this system. It is also timely to understand the university financial situation.

University financial data warehouse index is established on the basis of enterprise financial management index, considering the nonprofit characteristics of Universities.

Step 1: Set key indexes in university financial subject data warehouse, then classify these key indicators according to decision making, these classifications of key indicators constitute the subject system, and set them to S_1, S_2,……,S_n;

When setting University financial data warehouse, indicators can be divided into two groups according to their additive property. Two index sets are shown in table1 and table 2. The data warehouse contains ninety-three indicators, $I=\{I_{1,}I_{2,\ldots,}I_{93}\}$.

These ninety-three indicators can be divided into eighteen categories according to financial accounting. These eighteen categories are elements of University Financial Analysis Subject. These eighteen elements are Income structure of universities (S_1), Expenses structure of universities (S_2), Overall analysis of assets (S_3), Liabilities overall analysis (S_4), Net assets overall analysis (S_5), Human resources analysis (S_6), Educational material resources analysis (S_7), University conditions improvement (S_8), Overall income level analysis (S_9), Self-financing capacity analysis) (S_{10}), Operational capability analysis (S_{11}), Universities profitability analysis (S_{12}), University solvency ability analysis (S_{13}), University development potential analysis (S_{14}), Human Resource utilization efficiency analysis (S_{15}), Financial resources utilization efficiency analysis (S_{16}), Total output effect analysis (S_{17}) and Fund expenditure performance analysis (S_{18}). Elements of the subject and indexes included in university financial data warehouse are as shown in table3.

$S=\{S_1, S_2, S_3, S_4, S_5, S_6, S_7, S_8, S_9, S_{10}, S_{11}, S_{12}, S_{13}, S_{14}, S_{15}, S_{16}, S_{17}, S_{18}\}$

Table 1. Additive University Financial Data Warehouse Index Set

Code	Index name	Code	Index name	Code	Index name
I_1	Funds	I_2	Central government funds	I_3	Local finance allocates funds
I_4	Self-raised funds	I_5	Education funds	I_6	Research funds
I_7	Total expenses	I_8	Funds expenses	I_9	Public expenses
I_{10}	Education expenses	I_{11}	Research expenses	I_{12}	Operating expenses
I_{13}	Subsidiaries expenses on ancillary units	I_{14}	Superior Expenses	I_{15}	Infrastructure construction by non-financial-assistance income
I_{16}	Total assets	I_{17}	Increase amount in assets	I_{18}	Total liabilities
I_{19}	Increase amount in liabilities	I_{20}	Total net assets	I_{21}	Increase amount in net assets

Table 2. Non-additive University Financial Data Warehouse Index Set

Code	Index	Code	Index	Code	Index
I_{22}	Growth rate in net assets	I_{23}	Student-faculty ratio	I_{24}	Senior position ratio
I_{25}	Building area per capita	I_{26}	Dormitory area per person	I_{27}	Fixed assets per capita
I_{28}	Equipment cost per capita	I_{29}	Grants expenses per capita	I_{30}	Development-total expenses ratio
I_{31}	Growth rate in fixed assets	I_{32}	Growth rate in net assets	I_{33}	Return on total assets
I_{34}	Funds income per capita	I_{35}	Funds income per faculty	I_{36}	Total funds income growth rate
I_{37}	Financial allocation /Total funds (Income)	I_{38}	Education funds/Total funds (Income)	I_{39}	Research funds/Total funds (Income)
I_{40}	Self-raised -total funds income ratio	I_{41}	Growth rate in self-raised funds	I_{42}	Funds self-sufficiency rate
I_{43}	Self-raised funds income per capita	I_{44}	Education funds/Total funds (in)	I_{45}	Education revenue per capita
I_{46}	Growth rate in education revenue	I_{47}	Research funds/Total funds (in)	I_{48}	Research funds per capita
I_{49}	Growth rate in research revenue	I_{50}	Donation /Total funds income	I_{51}	Growth rate in donation income
I_{52}	Funds income-expense ratio	I_{53}	Assets turnover	I_{54}	Public fund /total expenses
I_{55}	Investment funds in public funds	I_{56}	Assets income ratio	I_{57}	Net assets income ratio
I_{58}	Rate of return on investment	I_{59}	Investment income growth rate	I_{60}	Rate of return on investment
I_{61}	Net contributes per capita	I_{62}	Non-financial contributes per capita	I_{63}	Asset-liability ratio
I_{64}	Asset-liability ratio on university-owned enterprises	I_{65}	Income-liability ratio	I_{66}	Payout ratio
I_{67}	Potential pay ability	I_{68}	Current ratio	I_{69}	Liability turnover
I_{70}	Ratio of bank loans to total liability	I_{71}	Assets Equity Ratio	I_{72}	Utilization rate of free funds
I_{73}	Utilization rate of other funds	I_{74}	Utilization rate of currency funds	I_{75}	Payout ratio in currency funds
I_{76}	Ratio of net funds to currency funds	I_{77}	Faculty-student ratio	I_{78}	Student-staff ratio
I_{79}	Faculty-staff ratio	I_{80}	Retired staff /Total staff	I_{81}	Personal expenses/Total expenses
I_{82}	Personal-public funds expenses ratio	I_{83}	Public expenses per capital	I_{84}	Education expenses per capita
I_{85}	Personal funds expenses per capita	I_{86}	Public funds expenses per capita	I_{87}	Published papers per faculty
I_{88}	Published books per faculty	I_{89}	Research awards per faculty	I_{90}	Teaching awards per faculty
I_{91}	Daily teaching funds expenses per capital	I_{92}	Daily teaching expenses in education expenses	I_{93}	Proportion of daily public expenses in education expenses

Table 3. Elements of Subject and Indexes Included in University Financial Data Warehouse

Elements of subject	Indexes included
S_1 (Income structure of universities)	I_1, I_2, I_3, I_4, I_5, I_6
S_2 (Expenses structure of universities)	I_7, I_8, I_9, I_{10}, I_{11}, I_{12}, I_{13}, I_{14}, I_{15}
S_3 (Overall analysis of assets)	I_{16}, I_{17}
S_4 (Liabilities overall analysis)	I_{18}, I_{19}
S_5 (Net assets overall analysis)	I_{20}, I_{21},I_{22}
S_6 (Human resources analysis)	I_{23}, I_{24}
S_7 (Educational material resources analysis)	I_{25}, I_{26}, I_{27}
S_8 (University conditions improvement)	I_{28}, I_{29}, I_{30}, I_{31}, I_{32}, I_{33}
S_9 (Overall income level analysis)	I_{34}, I_{35}, I_{36}, I_{37}, I_{38}, I_{39}
S_{10} (Self-financing capacity analysis)	I_{40}, I_{41}, I_{42}, I_{44}, I_{46}, I_{47}, I_{49}, I_{50}, I_{51}
S_{11} (Operational capability analysis)	I_{52}, I_{53}, I_{54}, I_{55}
S_{12} (Universities profitability analysis)	I_{56}, I_{57}, I_{58}, I_{59}, I_{60}, I_{61}, I_{62}
S_{13} (University solvency ability analysis)	I_{63}, I_{64}, I_{65}, I_{66}, I_{67}, I_{68}, I_{69}, I_{70}
S_{14} (University development potential analysis)	I_{71}, I_{72}, I_{73}, I_{74}, I_{75}, I_{76}
S_{15} (Human Resource utilization efficiency analysis)	I_{77}, I_{78}, I_{79}, I_{80}
S_{16} (Financial resources utilization efficiency analysis)	I_{81}, I_{82}, I_{83}, I_{84}, I_{85}, I_{86}
S_{17} (Total output effect analysis)	I_{87}. I_{88}. I_{89}. I_{90}

S_{18} (Fund expenditure performance analysis)	I_{91}. I_{92}. I_{93}

Step 2: Establish adjacency matrix and calculate the reachability matrix

Here we define the relationship between S_i and S_j is that whether indexes in S_j are used to calculate indexes in S_i. If indexes in S_j are used to calculate indexes in S_i, then x_{ij} is 1, otherwise, x_{ij} is 0. According to this method, we established adjacency matrix A. Then we use MATLAB to calculate the reachability matrix R of the system by computing the adjacency matrix.

Table 4. The Adjacency Matrix for Elements of Subject in University Financial Data Warehouse

A	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	0	0	0	0	0	1	1	0	1	1	1	1	1	0	0	0	1	0
2	0	0	0	0	0	1	1	0	0	0	1	1	1	1	0	1	0	1
3	0	0	0	0	1	0	1	1	0	0	0	1	1	1	0	0	0	0
4	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
5	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0
6	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	1	1	1
7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5. The Reachability Matrix for Elements of Subject in University Financial Data Warehouse

R	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1
2	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	1	0	1	0	1	1	0	0	1	1	1	1	0	1	0	0
4	0	0	0	1	1	0	0	1	0	0	1	1	1	1	0	0	0	0
5	0	0	0	0	1	0	0	1	0	0	1	1	0	1	0	0	0	0
6	0	0	0	0	0	1	0	1	1	1	1	1	0	0	1	1	1	1
7	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	1	0	0
8	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Step 3: Derive reachability set and antecedent sets from the final reachability and establish level structure.

The top level (L_1) is shown in table 6. This process is continued until the level of each element is found. The results of derived levels are as fellows.

Table 6. The Top Level Elements Set (L_1) Analysis

S_i	$R(S_i)$	$A(S_i)$	$R(S_i) \cap A(S_i)$
S_1	$S_1,S_6,S_7,S_8,S_9,S_{10},S_{11},S_{12},S_{15},S_{16},S_{17},S_{18}$	S_1	S_1
S_2	$S_2,S_6,S_7,S_8,S_9,S_{10},S_{11},S_{12},S_{14},S_{15},S_{16},S_{17},S_{18}$	S_2	S_2
S_3	$S_3,S_5,S_7,S_8,S_{11},S_{12},S_{13},S_{14},S_{16}$	S_3	S_3
S_4	$S_4,S_5,S_7,S_8,S_{11},S_{12},S_{13},S_{14},S_{16}$	S_4	S_4
S_5	$S_5,S_8,S_{11},S_{12},S_{14},$	S_3,S_4,S_5	S_5
S_6	$S_6,S_8,S_9,S_{10},S_{11},S_{12},S_{15},S_{16},S_{17},S_{18}$	S_1,S_2,S_6	S_6
S_7	S_7,S_8,S_{11},S_{16}	S_1,S_2,S_3,S_7	S_7
S_8	S_8,S_{11}	$S_1,S_2,S_3,S_4,S_5,S_6,S_7,S_8$	S_8
S_9	S_9	S_1,S_2,S_6,S_9	S_9
S_{10}	S_{10},S_{11}	S_1,S_2,S_6,S_{10}	S_{10}
S_{11}	S_{11}	$S_1,S_2,S_3,S_4,S_5,S_6,S_7,S_8,S_9,S_{10},S_{11}$	S_{11}
S_{12}	S_{12}	$S_1,S_2,S_3,S_4,S_5,S_6,S_{12}$	S_{12}
S_{13}	S_{13}	S_1,S_2,S_3,S_4,S_{13}	S_{13}
S_{14}	S_{14}	S_2,S_3,S_4,S_5,S_{14}	S_{14}
S_{15}	S_{15}	S_1,S_2,S_6,S_{15}	S_{15}
S_{16}	S_{16}	$S_1,S_2,S_3,S_6,S_7,S_{16}$	S_{16}
S_{17}	S_{17}	S_1,S_2,S_6,S_{17}	S_{17}
S_{18}	S_{18}	S_1,S_2,S_6,S_{18}	S_{18}

From table 6, L_1 is derived. $L_1=\{S_9, S_{11}, S_{12}, S_{13}, S_{14}, S_{15}, S_{16}, S_{17}, S_{18}\}$;

Table 7. The Second Level Elements Set (L_2) Analysis

S_i	$R(S_i)$	$A(S_i)$	$R(S_i) \cap A(S_i)$
S_1	S_1,S_6,S_7,S_8,S_{10}	S_1	S_1
S_2	S_2,S_6,S_7,S_8,S_{10}	S_2	S_2
S_3	S_3,S_5,S_7,S_8	S_3	S_3
S_4	S_4,S_5,S_7,S_8	S_4	S_4
S_5	S_5,S_8	S_3,S_4,S_5	S_5
S_6	S_6,S_8,S_{10}	S_1,S_2,S_6	S_6
S_7	S_7,S_8	S_1,S_2,S_3,S_7	S_7
S_8	S_8	$S_1,S_2,S_3,S_4,S_5,S_6,S_7,S_8$	S_8
S_{10}	S_{10}	S_1,S_2,S_6,S_{10}	S_{10}

From table 7, L_2 is derived. $L_2=\{S_8, S_{10}\}$;

Table 8. The Third Level Elements Set (L_3) Analysis

S_i	$R(S_i)$	$A(S_i)$	$R(S_i) \cap A(S_i)$
S_1	S_1, S_6, S_7	S_1	S_1
S_2	S_2, S_6, S_7	S_2	S_2
S_3	S_3, S_5, S_7	S_3	S_3
S_4	S_4, S_5, S_7	S_4	S_4
S_5	S_5	S_3, S_4, S_5	S_5
S_6	S_6	S_1, S_2, S_6	S_6
S_7	S_7	S_1, S_2, S_3, S_7	S_7

From table 8, L_3 is derived. $L_3=\{S_5, S_6, S_7\}$;

Table 9. The Fourth Level Elements Set (L_4) Analysis

S_i	$R(S_i)$	$A(S_i)$	$R(S_i) \cap A(S_i)$
S_1	S_1	S_1	S_1
S_2	S_2	S_2	S_2
S_3	S_3	S_3	S_3
S_4	S_4	S_4	S_4

From table 9, L_4 is derived. $L_4=\{S_1, S_2, S_3, S_4\}$;

Step 5: Set the bottom level L_4 and remaining level L_1, L_2, L_3 to basic level L_b and analysis level L_a in the system level structure. The top level L_1 is set to the value level L_v. Then establish a subject-level model.

Table 10. The University Financial Data Warehouse Subject Levels

Subject Level		Code of subject elements	Name of the subject elements
L_b		S_1	Income structure of universities
		S_2	Expenses structure of universities
		S_3	Overall analysis of assets
		S_4	Liabilities overall analysis
L_a		S_5	Net assets overall analysis
		S_6	Human resources analysis
		S_7	Educational material resources analysis
		S_8	University conditions improvement
		S_{10}	Self-financing capacity analysis
	L_v	S_9	Overall income level analysis
		S_{11}	Operational capability analysis
		S_{12}	Universities profitability analysis
		S_{13}	University solvency ability analysis
		S_{14}	University development potential analysis
		S_{15}	Human Resource utilization efficiency analysis
		S_{16}	Financial resources utilization efficiency analysis
		S_{17}	Total output effect analysis
		S_{18}	Fund expenditure performance analysis

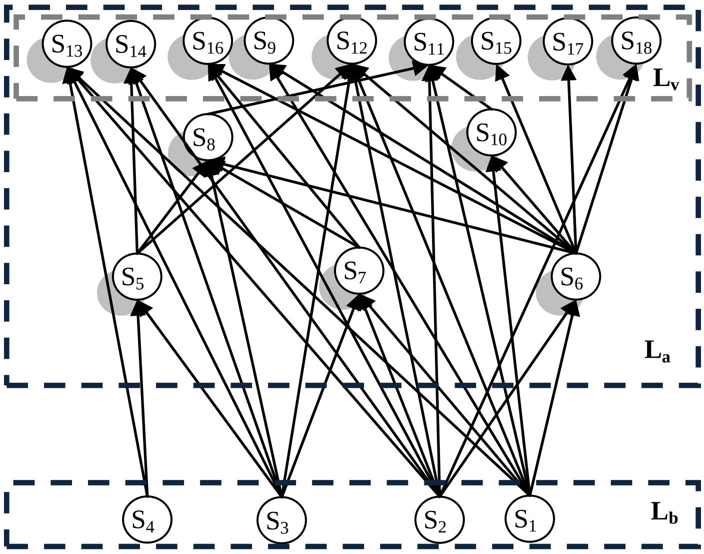

Figure 1. Level Structure of University Financial Analysis Subject based on ISM

As it is shown in Fig.1.We finally obtain hierarchy structure of University Financial Analysis Subject based on Interpretative Structure Modeling. Basic level of the University Financial Analysis Subject consists four elements (Income structure of universities, Expenses structure of universities, Overall analysis of assets and Liabilities overall analysis) that are most fundamental among those elements. This result coincides with knowledge of financial management. Income and expenses are significance component in income statement that is a direct result of the information that transformed recorded in the journals and ledgers into concise, compiled revenue and expense figures to be used by management. Assets and liabilities as remarkable parts in balance sheet are also fundamental to managers of university in reality. Because net worth of the business that is the difference between the assets and the liabilities is a measurement of the time the business is expected to stay in financial power. Moreover, It also provides the business with information on how best it is able to pay its debts. Hence, this Level structure of University Financial Analysis Subject is not conflict with the real financial management. The important feature of this structure is that it is established from the perspective of hierarchy system modeling and university financial requirements.

4. Conclusion

Elements of subject are divided into base level and analysis level. There is a special level named value level, which is a collection of elements that provide decision makers with most valuable information. This paper presents a general method based on ISM to establish subject level structure in data warehouse. The advantage of this method is that it introduces quantitative tools, such as directed graph, adjacency matrix and reachability matrix to partition subject level in data warehouse. A case on university financial data warehouse's subject level structure establishment verifies the rationality and validity of the method. This method gives a new idea for establishing data warehouse's subject level.

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