Linking System Dynamics Model to Data Modeling

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Abstract

Traditional top-down design of databases is unable to fulfill managerial information needs. A database is supposed to contain all the information required for decision making. However, the information requirements are not only uneasy to identify but also variable in the dynamic complex environment. The value of a database to support management may decline. The research is concerned about how to define management information requirements clearly and effectively. In the paper, system dynamics' models are combined into the information requirement analysis stage of database planning. Both operational and managerial information requirements can be extracted and derived by transforming system dynamics models to data models. In addition to support database design, system dynamics' model also provide managers the opportunity to aware how they used to perceive and interpret decision tasks.

1. Introduction

Database has become a core technology in organizational computing. A database contains most of organization's digitized data. With those digitized data, daily transactions and routine works can be done more efficiently, and the effectiveness and timeliness of management and control activities can be improved also. To satisfy an organization's information needs, system analysts use top-down planning and bottom-up designing approaches. Top-down planning is to extract an enterprise data model that will be the blueprint for later development and integration of each separate database. In the enterprise model, future organizational development is supported. Besides, bottom-up designing approach is used to decompose the enterprise data model and to implement physical databases according to their priorities..

General top-down analysis procedure(Mcfadden et al., 1993) starts from organization's strategic planning. Then, managers transform the result of strategic planning into sub-goals and more detailed activities. According to the nature and contents of those activities, data items to be processed are identified. In addition, relationships among data items are also derived from operational characteristics and

constraints. The final result in this information requirements analysis is called data model.

The resulting data model is expected to provide information for operational activities and to support managerial decisions. However, it does not work well as its expectancy. Organization’s strategies and goals may change frequently; database can not satisfy mangers' information needs; information systems are inflexible, etc.(King, 1978; Lederer & Sethi, 1988; Lederer, 1991). In essence, because managers’ decision tasks are unpredictable, managers cannot identify their information requirements well. Furthermore, because most of management environments are dynamic and complex, cognition structure inconsistency happens to managers frequently. In such circumstances, managers feel that they need more information to resolve their cognition structure inconsistency, but they may not know exactly what information they need. The original information needs may be distorted or lost in the top-down transformation process.

The paper attempts to use system dynamics to support database planning. Information requirements are defined more effectively, and the priorities to develop sub-data models are also determined.

2. Data Model

The content of a data model can be divided into two parts. One is data items, the other is the way data items are organized. The data model is one kind of data structure representations. Its purpose is to provide data to support each level of organizational activities, such as operational and managerial activities(Dehayes, 1990). In practice, different levels of organizational activities should have different information requirements and data models. Most of the database designs are built on the operational-level data model, while data model or information requirements of other organizational levels are ignored. Several kinds of data models are proposed and developed, for example, hierarchical data model, network data model, relational data model, and object-oriented model, etc. Because relational database is most popular nowadays, the paper is supposed to use it to illustrate the research.

A relational data model is composed of entity types and relationship types. Entity types are objects that physically exist and they can be described by their attributes. Relationship types are relationships among entity types. Entity types are obtained from information requirements analysis, while relationship types are primarily extracted from operational rules and constraints.

When a database is unable to satisfy users' information needs, there might be two problems with the data model. One is that data model does not contain appropriate entity types for required data items. This occurs when the information requirements are uncertain and difficult to identify. The other problem is that the relationship types defined in the data model are incomplete or incorrect. Both of the two problems happen more frequently in the dynamic and complex environment.

3. The Role of System Dynamics Modeling in Database Planning

Database planning has two phases. The first phase is to derive information requirements from an organization's strategic planning and operational activities. The second phase is to transform the information requirements developed earlier into a data model and to design the physical database. The quality of a database is determined mostly by the success of first phase.

Morecroft(1984) indicates that if a model is to be effective in support of strategic planning, it must be (1) down from the pedestal of the infallible black box to occupy a more modest position as a complement to the thinking and deducing powers of management; (2) a vehicle for extending argument and debate; (3)a generator of opinions, not answers, and managers must be encouraged to challenge and debate model conclusions. System dynamics' models are able to satisfy those requirements. Prior research has suggested several ways to implement system dynamics models in strategic planning(Morecroft, 1984, 1985; Morecroft et al., 1991; Risch et al., 1995). The paper extends prior research to support managerial information requirements analysis.

In addition to managerial requirements, operational information requirements can also be derived from system dynamics' models. In terms of isomorphism, the characteristics of operational processes are reflected in system dynamics' models. Hence, actual operational processes can be elicited from the system dynamics' models. According to those processes, operational information requirements can be acquired

With system dynamics' models, managerial information requirements can be more explicit and operational information requirements can be obtained more easily. And multiple-level transformation processes are eliminated. Techniques to transform system dynamics' models to data models will be discussed in detail.

4. The Linkage between Data Model and System Dynamics Model

As described above, data model can be established from the transformation of system dynamics' models and the analysis of operational processes. This section is devoted to illustrate how the transformation processes proceed.

In system dynamics models, level is the major information provider. If we look at levels more closely, tangible and intangible levels are present. For examples, people, money, equipment, and orders (Forrester, 1961)are tangible levels, while stress and cognition are intangible levels. In the data model, only tangible levels are included as data items(entity type). Further, through different kinds of computation processes, extended tangible level can be obtained from original tangible levels. If the data model support management function, then these original tangible levels should be included into the data model. Rate equations point out what users' view are. Users' view is a subset of data model, which is information needed when making a decision. Because users' view is extended information from levels, it is used just for user interface design.

However, a data model should include more than data items obtained from the transformation of system dynamics' models. To support those policy designed in system dynamics' models, a data model should provide information for operational processes. Operational information requirements can be obtained from the analysis of operational processes. After obtaining managerial information requirements from the system dynamics model, analysts have to find out basic operational processes indicating by the model. With traditional requirement analysis methodology, those processes are analyzed and the conceptual data model design is finished.

Besides, in terms of technical consideration, it may be inefficient to query some users' views involving many complex data transformations. In order to increase the database's performance, such users' views can be materialized into the database.

5. Conclusion

The effectiveness of a database is dependent on the completeness of its data model. However, in variable environments, traditional database planning is unable to acquire stable and concrete information requirements. Furthermore, information losses and biases arise more frequently. The research attempts to use system dynamics models as a vehicle to induce and extract organization's information requirements. Three advantages emerge by doing so. First, it is more effective in dealing with strategic issues. Second, it is easier to define more clear and more

stable information requirements for operational and managerial support. Finally, it can help information users to emphasize on the assumptions and interpretations they made. With system dynamics' models, realization of what's valuable information and what information managers really need is deepened.

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