AD-A089 321 WHARTON SCHOOL PHILADELPHIA PA DEPT OF DECISION SCIENCES F/G 5/1
MODEL MANAGEMENT SYSTEMS: AN OVERVIEW.(U)
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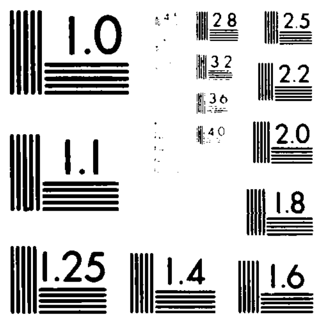

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MODEL MANAGEMENT SYSTEMS: AN OVERVIEW

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79-12-04

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This research was supported in part by ONR Contract No. N00014-75-C-0440.

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: 79-12-04

2. GOVT ACCESSION NO.: AD-A089 321

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): MODEL MANAGEMENT SYSTEMS: AN OVERVIEW

5. TYPE OF REPORT & PERIOD COVERED: Technical Report

6. PERFORMING ORG. REPORT NUMBER: 79-12-04

7. AUTHOR(s): Joyce J. Elam

8. CONTRACT OR GRANT NUMBER(s): N00014-75-C-0440

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
Department of Decision Sciences
The Wharton School/Univ. of Pennsylvania
Philadelphia, PA 19104

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Task NR049-360

11. CONTROLLING OFFICE NAME AND ADDRESS:
Office of Naval Research
Information Systems
Arlington, VA 22217

12. REPORT DATE: December 1979

13. NUMBER OF PAGES: 8

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report):

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report):

18. SUPPLEMENTARY NOTES:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

(MMS)model management system; management science models; decision support system; database management system

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

This paper presents an architecture for a generalized model management system that facilitates the integration of management science models into a decision support system. The model management system will provide a methodology for making mapping more scientific. The linking together of models with data and solution processes is a difficult and time-consuming process for a user of such models. The model management system will automate this linking as much as possible.

MODEL MANAGEMENT SYSTEMS: AN OVERVIEW[1]

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ABSTRACT

This paper presents an architecture for a generalized model management system that facilitates the integration of management science models into a decision support system. The mapping of a decision into some structured representation (model) is currently an art rather than a science. The model management system will provide a methodology for making this mapping more scientific. The linking together of models with data and solution processes is a difficult and time-consuming process for a user of such models. The model management system will automate this linking as much as possible.

INTRODUCTION

This paper presents a general framework for the development of a model management system (MMS) that facilitates the use of mathematical models and techniques by a decision-maker in an interactive problem solving environment. The objective of the system is to support the decision-maker both in specifying a problem and in effecting a solution. This is accomplished by providing him/her with a means for interacting with a complex structured database to construct a model(s) of some problem, to find, if available, a previously developed model(s) for the problem, and to solve the model(s) defined for the problem using appropriate information--either from the database or some other source--and efficient solution procedures.

The philosophy which underlies the design of this system is (1) models, like data, are an organizational resource and can be described, executed, and manipulated by some generalized software system and (2) a general framework can be designed for managing a variety of model types (optimization, heuristic, statistical, simulation, descriptive, etc.). By viewing models in an analogously way as data, much of the recent research in database management systems can be applied to this research.

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[1] This research was supported in part by ONR contract No. N00014-75-C-0440

NEED FOR RESEARCH

The problems facing today's decision-maker are highly complex, are continually changing as better information and/or knowledge becomes available, and require immediate attention. In addition, the data that impacts on solutions to these problems is voluminous, dynamic, and may originate from many sources. The complexity of these problems has necessitated the use of mathematical models and efficient data management capabilities to organize the voluminous amounts of data into useful information.

Although considerable research has been directed toward enhancing data management capabilities and developing computationally efficient algorithms for solving a variety of models, little research has been directed toward integrating the technologies of database management and management science. Database management systems have not been designed with the goal of supporting analytical techniques. Correspondingly, analytical systems have assumed that the problem to be analyzed has been structured and is represented in some standard form. These systems have not addressed the issues involved with structuring the problem and preparing the data associated with the problem in some standard format.

This lack of integration has resulted in current database management systems that are used for operational control or management control in organizations. The major concerns of such systems are with the raw data of an organization. In general, current systems do not have the capabilities to support higher-level decision making. The lack of integration has also resulted in mathematical techniques not being effectively used. An extremely important aspect for the implementation, use, and acceptance of a mathematical model is its informational requirements and accessibility. Too often it is difficult if not impossible to extract the data needed for an analysis from the organizational data base. Even if the data is obtained, it is up to the user to reformat the data required by the model to conform to the data requirements of the analytical software system to be used.

The major impact of management science has been on structured problems where the decision-maker can be provided with detailed recommendations for handling these problems[7]. Expanding the use of management science techniques for supporting the decision-making required by less structured problems requires a more extensive involvement of the decision-maker. The MMS will facilitate this involvement.

FRAMEWORK FOR DESIGN

Objectives

Effective model management encompasses all phases of model activity--construction, testing, execution, validation and maintenance-- and facilitates the use of models that are simple, robust, easy to control, adaptive, complete on important issues, and easy to communicate with [8]. The major objectives of the model management system can be broadly defined as follows:

1. The MMS should facilitate the structuring of a problem so that analytical tools can be used in generating possible solutions.

2. The MMS should facilitate the processing and analysis of structured representations (models) of problems.

In order to meet these objectives, an architecture is proposed for the MMS which consists of three basic components: users, model knowledge base, and functional subsystems. These components are described below.

Users

Users interface directly with the MMS in various roles. These roles can be broadly classified as the model user, the model builder, the model implemementor, and the model administrator. These roles involve different phases of the modeling activity. A single person or a group of persons may assume any one of these roles (or a combination of roles) in an organization. A similar classification of users' roles was proposed in [6].

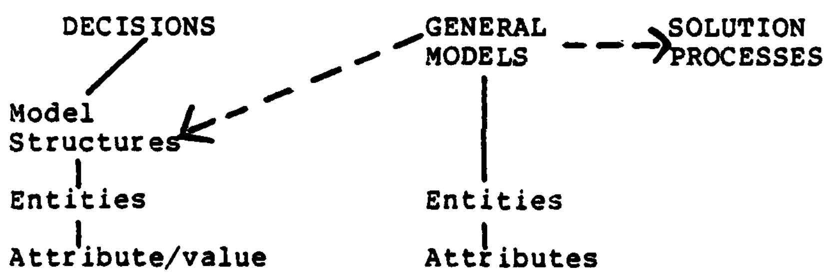
The model user interacts with the MMS at a high level to find and execute previously developed models. The model user is typically a non-programmer who requires minimal knowledge of the system. The model builder interacts with the MMS to construct models. The model builder is supplied with commands for data collection, data analysis, and model assembly. The model builder is a sophisticated user of the system but is not necessarily a computer programmer. The model implementor interacts with the MMS to provide the interfaces between model definition, data requirements, and model processing programs that are necessary to support automatic model execution and validation. As a person with computer programming skills, the model implementor may also provide the computer programs necessary for model processing. (These may also be supplied from other sources.). The model administrator has overall responsibility for the MMS. He/she ensures that the MMS objectives are met in the most efficient manner and is responsible for model debugging, testing, validation, documentation, accounting, and access.

Model Knowledge Base

The model knowledge base contains the information necessary to support the various model management activities and objectives. In many ways, the model knowledge base is to the MMS as the database is to a database management system. A distinguishing characteristic of database management systems is the separation of the logical description of data from its physical representation in the database. In a similar manner the model knowledge base separates the physical representation of a model from the logical description of the model. The contents of the model knowledge base are shown in Figure 1.

FIGURE 1

Model Knowledge Base



A general model represents some well-structured and easily identifiable process such as linear programming, inventory analysis, utility-based state model, forecasting, etc. A solution process represents the actual programming code used to solve a general model. Every general model can be characterized by a set of entities, a set of relationships between these entities, and a set of assumptions upon which these relationships are based. The entities and relationships are described by a set of attributes that either represent inputs to the general model (controllable attributes) or represent outputs from the general model (uncontrollable).

The interest of the MMS model user and model builder is not, however, in general models but in specific problems. A specific problem is called a decision. A decision is divided into primitive elements where each element is a specific instance of a general model. These elements are called model structures. The entities and attributes that characterize a model structure correspond one-to-one with the entities and attributes that characterize its general model. A model structure, however, provides a logical link between attribute names and data values. For controllable attributes, this link involves data that is user-supplied or created as a result of some previous model process. For uncontrollable attributes, this link specifies whether the data values produced by a solution process are to be stored in a database, reported to a user, and/or supplied as input to another model structure.

Functional Subsystems

The MMS is divided into three major subsystems: Model Development, Model Processing, and Model Administration. All subsystems interact directly with the model knowledge base described above. The functions contained in each subsystem and the interactions with the model knowledge base are detailed below.

The basic functions of the Model Development subsystem are to (1) support interactive model building and (2) to provide information about previously defined decisions, model structures, general models, and solution processes.

The process of model building involves data collection, data analysis, and model assembly. We assume that the data to be collected is contained either in the operational database of the organization or in a special model-related database. The databases are assumed to be accessible to the MMS through a query language. These languages are available in many database management systems and can easily be interfaced with the model building subsystem. The major focus of the model building subsystem will be on model assembly. (Data analysis can be viewed in the same manner as any model which is built, executed, and analyzed through the MMS and data collection is supported by some database management system.)

The mapping of a decision into some structured representation than can be processed using general analytical tools is currently an art rather than a science. The model building subsystem will attempt to make this mapping more scientific. The design of this subsystem is based on the premise that the process of structuring some problem can be supported by identifying general models that are applicable to the decision of interest and using the structures provided by these general models to develop specific model structures. By linking model structures to general models and solution processes to general models, a wide range of specific model structures can be processed within the MMS.

It is to be expected that at some time the model builder will attempt to build a model structure that does not have an existing general model counterpart stored in the model knowledge base. In this case, the model building system allows a model structure to be created by the model builder.

The system then creates a new general model in the model knowledge base. Since no solution process exists for this newly created general model, one must be developed by the model implementor and added to the model knowledge base. In this way, the model knowledge base evolves over time to reflect the expertise and experience gained by the users of the MMS.

Another major function included within model development is the model dictionary. The model dictionary subsystem supports users in determining what types of decision model structures, general models, and solution processes exist in the model knowledge base.

As explained above, data values are associated with the attributes that define a model structure. Model processing involves the physical linking of data values to these attributes. The linking of data values to controllable attributes is referred to as creating a model instance. The linking of a model instance to a solution process is referred to as model execution. The linking of data values to uncontrollable attributes is referred to as model solution. Model processing will perform this linking in much the same manner as proposed in [6]. The system will do what linking it can automatically and will leave the rest to the user.

Model processing interacts with the database, the model knowledge base, and/or users. If the source of any controllable attribute is a model process, a submodel instance is created and processed in order to obtain the appropriate data values. The linking of a model instance to a solution process is accomplished through its association with a general model. Input and output requirements of a solution process are specified in terms of a general model. In this way, many different model instances may use the same solution process.

Although the MMS will automate the linking process as much as possible, it is expected that some interaction between the user and the system may be necessary. Additional information can be added to a particular model structure definition that would minimize the need for user interaction in executing the model. This would be desirable for frequently executed models.

Once a model has been solved, the results can be presented to a user, stored in the database, or used in another process. The Model Processing System again interacts with the model knowledge base and database to output the results in the appropriate way.

Model Administration is concerned with model validation and model maintenance. The model validation subsystem is responsible for monitoring the model assumptions and informing a user when the assumptions are violated during model processing. The model assumptions can be specified in a similar manner as integrity constraints in database management systems [1]. The model validation system should aslo provide capabilities for both replicatively and predictively validating a model.

CONCLUSIONS

The purpose of this paper has been to outline the architecture for a generalized model management system that facilitates the integration of management science models into a decision support system. The MMS provides support for the modeling activity through Model Development, Model Processing and Model Administration. Through model development, a decision-maker can develop a structured representation of some decision and relate this representation to other operating models within the system. Model processing provides a high-level mechanism for interfacing data, models, and solution processes so that the user is relieved of low-level data management functions. Model administration allows the collection of models to be treated as an organizational resource and managed accordingly.

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