KBSIM

A Knowledge Based Tool And Its Use In Model Preprocessing

David F. Young
The Timken Company and
Paradigm Systems Research Group

ABSTRACT

This article describes a tool called KBSIM and its use in model preprocessing. KBSIM consists of a knowledge acquisition system and a systems knowledge modeler which translate the responses of human tutors into structural models and facts housed in a system knowledge base. KBSIM accesses and manipulates the knowledge base through an iterrogation engine to produce information on the structure and function of a described system. KBSIM's knowledge base is a hierarchical set of matrix mapped structural models of a system to an expert level of detail. The tool is useful in integrations and strategic management, technology selection and systems modeling and analysis.

INTRODUCTION

To effectively deal with the high orders of complexity so commonly encountered in today's technological systems, a tool that discovers and coordinates internal system linkages to an expert level of detail is required. The tool must have the capability to describe any system, regardless of complexity and subject, in a way that yields to analysis through a suitable set of interrogation techniques. The tool must be practical, readily implementable, provide system understanding on many levels, direct and minimize the collection of data, coordinate human resources in the analysis, provide management integrations information, and support integrated decision making in a verifiable and comprehensible fashion. Knowledge Based Systems Interrogation and Management (KBSIM) is an analysis and management tool meeting these requirements.

COMPLEX SYSTEMS

System complexity is a function of entity number, scope, linkage, and clarity. An entity is any element, attribute, state, concept, or event that can be singularly identified in a system. "Scope" refers to the disciplines or knowledge areas covered by the system entities. "Linkage" is concerned with the number and strength of the direct and indirect relationships between system entities. "Clarity" refers to the definability of an entity or the crispness of an entity's definition.

Good decisions result from a clear understanding of a system, its environment, and the desired system objectives. Traditional management and analysis techniques work well for certain classes of systems and environments but with increasing complexity, the techniques stumble. The problem lies in the scope of the knowledge base brought into the analysis process. A "knowledge base" refers to the cumulative, captive, and accessible knowledge that can be drawn on in the decision making or analysis process. In most organizations, the knowledge base is what the decision maker knows of the system and a collection of opinions and recommendations from specialists further down in the organizational hierarchy. There is not a comprehensive understanding of the system to an expert level of detail. The system is viewed in a fragmentary fashion which is increasingly detrimental with system complexity.

In dealing with complexity, human beings decompose a system into smaller, understandable units. In organizations, the smaller units become technical, process, or administrative specialties. Each speciality understands the system from its own technical, process or administrative perspective. The knowledge base in each speciality is the information captive and accessible to practioners in that speciality. When making decisions, an attempt is made to synthesize the perspectives of independent specialties to provide a general system picture. In highly linked systems, traditional synthetic management approaches fail; the knowledge base from which decisions are made is a poorly collected and connected set of specialists' perspectives.

A technology system exists to meet needs. It is managed to attain desired goal behavior and as the goals change, efforts to alter system behavior to attain the new goals are undertaken. Decisions are made and programs implemented which are designed to positively alter system performance. The decisions and programs are built from some knowledge base of the system. More exactly, they are built from some understanding of what the system is and how it will change when altered in a given manner; that understanding is called a mental model. Everything human beings do is done from a mental model of a system. That model determines what actions are taken based on the expected outcome of those actions. In highly linked systems, managing change is difficult. The domino effects of any action may alter the system in unanticipated ways. The linkages in the system carry the change from one entity to another influencing the behavior of the system. Human beings form mental models of systems in ways that account for direct links between entities but obscure the indirect relationships betweens system entities. Many mental models never clearly separate direct from indirect relationships in a system. The result of fuzzy and incomplete mental models is poor or less effective system management and the inability to cause desired system changes. Fuzzy mental models compounded with a fragmentary synthesis of several specialists' recommendations makes managing creative change difficult.

CALL THE EXPERT

To make good decisions, to manage change, available expertise must be saddled for the decision making and management process. Each specialist has a mental model of his system and works accordingly. Harnessing the specialist, the expert, for a management activity brings his mental model of the system into the management process. Synthetic management techniques rely on integrating experts' perspectives into technology management efforts. We have indicated that the integration of these experts is difficult and fragmentary, that even the experts' mental models of the system are fuzzy and biased.

Experts are the fundamental source of detailed information about the composition and function of a system. They have insight into some portion of a system and historical experience in its behavior. They have a special view of the system which effects how they work and direct a portion of a system. Any serious effort in managing highly linked systems must involve experts in each system speciality incorporating their perspective and understanding.

AN INTEGRATED SYSTEMS MANAGER

Ideally, any decision, analysis or management activity in a highly linked system must integrate the mental models that experts have about their fraction of the system. We have discussed the necessity to incorporate information on system characteristics, particularly entity linkages, in any competent system examination; that information is captive in the minds of system experts. To make decisions from a system perspective, we must distill, coordinate, and validate experts' knowledge on the system's composition and structure.

If what experts know of the system could be captured and accessed when making decisions about the system, the effectiveness of management, analysis, and decision activities would improve. Imagine the benefits of a manager who knew the entire system structure to an expert level of detail, who had a crisp mental model of the entire system. Such an "integrated systems manager" could analyze the domino effects of changes in the system and understand the results of actions on system entities. To work on highly linked systems, we need an integrations expert; we need to put the experts' knowledge of their individual subsystems and the interaction of those subsystems at the disposal of decision makers of subsystem practitioners.

BUILDING AN EXPERT

We must build the capability to uncover, store, coordinate, and manipulate the mental models of specialty experts and provide a system perspective to an expert level of detail. The technique to build an integrations expert involves a knowledge acquisition system, a systems knowledge modeler, a structural knowledge base, an interrogations engine, and a communications producer. Figure 1 provides a functional plan of the components necessary to build a system expert.

The knowledge acquisition system is responsible for coordinating the search to discover the way specialty experts view their fraction of the system. It requests the identification and detailing of system entities, linkages between entities, and subsystem interfaces. The knowledge acquisition system is a structured, interactive computer process that issues activities and receives system knowledge. The system knowledge modeler, working with the knowledge acquisition system, formulates a structural model of an expert's mental model of his system. Uncovering mental models is done interactively by the knowledge acquisition system which pumps information into the knowledge modeler. The models assembled by the knowledge modeler are stored in a systems knowledge base. When the knowledge acquisition process is complete, the knowledge base will hold each specialist's mental model in a structured and accessible form. The interrogation engine is a series of routines designed to dissect the knowledge base and examine linkage between system entities providing information on system structure and casual chaining. The interrogation engine also preprocesses and develops nucleus system models. Working with each element of the technique, the communications producer issues documents and charts to aid the acquisition and reporting of system information. Together, the knowledge base, interrogation engine, and communications producer act as an integrated systems expert possessing a verified global model, developed by the system specialists, of the entire system to an expert level of detail.

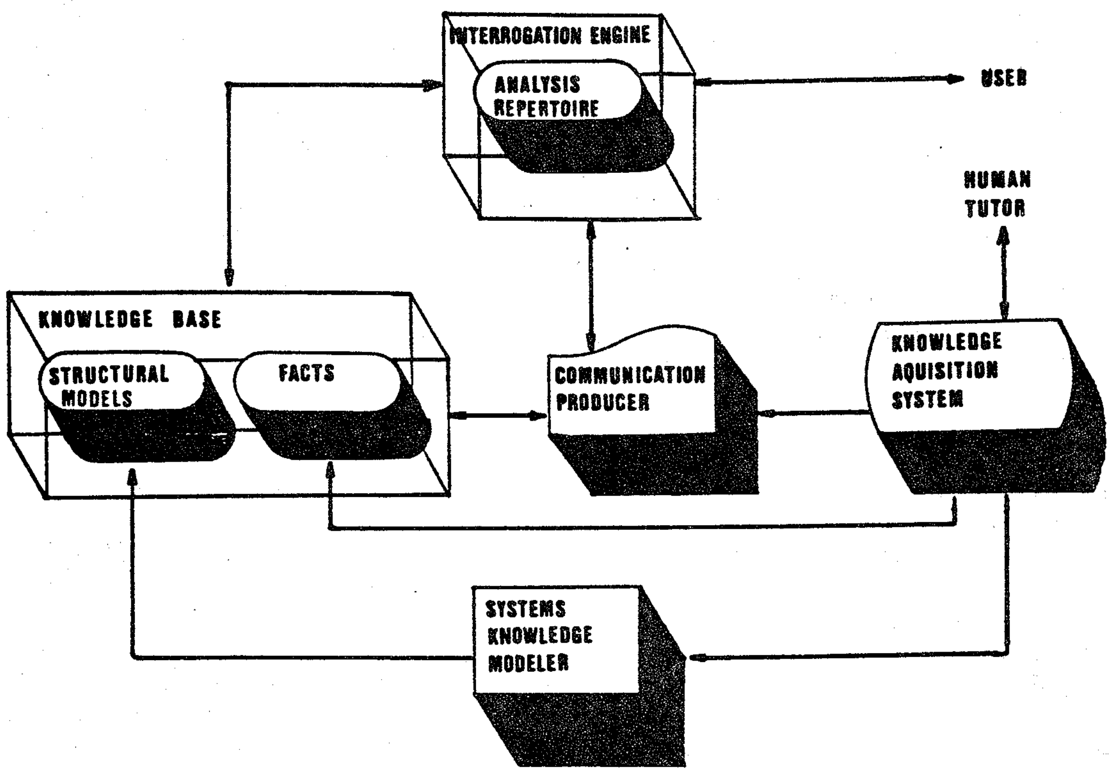

Figure 1 KBSIM Architecture

INTERROGATION ENGINE The set of computer techniques that dissect a knowledge base to examine linkages between system entities providing information on system structure and causal chaining

KNOWLEDGE ACQUISITION SYSTEM The structured, interactive computer and manual process that issues activities and receives system knowledge

KNOWLEDGE BASE The cumulative, captive, and accessible knowledge that can be drawn on in the decision making or analysis process; the computer held representation of experts' conceptual models of a system being studied

SYSTEMS KNOWLEDGE MODELER The procedure set which formulates structural models from a tutor's mental model of a system

TEACHER AND PUPIL

Fundamental to the construction of an integrations expert, specialists work with the knowledge acquisition system submitting information on the entities and structure of the system being inspected. Each selected specialist reveals in a directed way his knowledge to the acquisition system. The knowledge modeler then generates models to be contained in the knowledge base. The structured knowledge acquisition process also clarifies concepts held by system specialists. They are forced to examine closely the way they think about their fraction of the system. Contemplating their perspective of the system, specialist may discover new insights into system behavior when forced to think about casual linkages between system entities. Every participant's operational knowledge improves during the knowledge acquisition process and the construction of the system knowledge base. Enhanced understanding of a system is an immediate payback to invested time and resources when using KBSIM. The specialist not only teach the acquisition system but teach themselves to think casually about their system.

EXPANDING KNOWLEDGE BOARDERS

Any system specialists knows a fraction of the system very well and has some fuzzy understanding of the overall system. Specialists, or experts, are often conscious of other subsystems or areas that directly affect them. They may not have a complete understanding of the other subsystems but can indicate what aspects of their system are affected by "outside" forces. In the knowledge acquisition process, experts are directed to examine these interfaces and provide knowledge about what and how their area is externally impacted. The system knowledge modeler, makes use of the interface information to expand earlier constructions and provide the knowledge base with models covering a larger part of the system. Each construction is validated and groomed during the interplay of the acquisition system, the knowledge modeler, and the knowledge base.

Examining interfaces promotes enhanced operational awareness among participants and focuses on extended casual aspects of the system. The creation of integrated systems models, bringing larger chunks of system knowledge together in the knowledge base, provides a perspective of the system which was never possible before.

INTEGRATED DECISION SUPPORT

With the completion of the system knowledge base, a suitable set of analytical techniques can be accessed to deal with the complexity of the system. The techniques allow the interrogation of system structure, access and manipulation of subsystem and interface data, coordination of subsystem activities for integrations management, and the effective use of system experts in extended analyses and applied systems management. Now decisions can be made about the system through the knowledge of subsystem experts.

Traditional approaches in analyzing and managing highly linked technological systems were criticized as ignoring the character of the system and drawing on a limited knowledge base of the system. KBSIM's knowledge base has a scope limited only by the practioners selected to pump the acquisition system and the structured knowledge acquisition activity assures the character of system is taken into account. True integrated decision support is provided by carefully applying the interrogation portfolio to a broad structured knowledge base.

MODELING COMPLEX SYSTEMS

Managing the systems of today means anticipating the needs of tomorrow and coordinating the present with the objectives of the future. This generally involves extrapolating the behavior of a current system in the altered environments of the future, a complex and risky endeavor but often very necessary. Extrapolating the behavior of a complex system is best done by dynamic modeling. Creation of a dynamic model is expedited by sifting the knowledge base for fragments of the captive conceptual models essential in representing the structure of some aspect of the system. KBSIM provides for creating, communicating, and managing systems models.

The highly linked nature of modern technological systems and technology structures poses a great challenge for modelers. A model must produce behavior which approximates the modeled system's behavior to a high degree. Additionally, this behavior must be produced by a structure like the legitimate system's structure. Verifying that a model's inner mechanisms represent actual aspects of the modeled system is difficult for modelers to accomplish and often more difficult for those involved with the system to believe. When the model becomes important to decision making, questions about the validity and reliability of the model become common. If the model is built from the perspective of an outside analyst, criticisms about the model's accuracy can carry enough weight to sink its use in decision making. No matter how the model is constructed, the basis of the model is fundamental to its validity. The closer a model's basis is to the actual system, the higher its representation capability and resulting validity.

Early in our discussions of knowledge base building, the concept was presented that a knowledge base is a collection of the conceptual models held by system experts. Any computer model results from translating a conceptual model into a programmed model which can be run on a machine. Specific modeling languages choose to represent elements of a conceptual model in a fashion which allows their manipulation along the lines of a specific modeling philosophy. But, the conceptual model is independent of the programmed model's language and serves only as the template for the model. The knowledge base built for a given system is the complete template for any model of the system, and that template is highly reliable, since it was built by those who know the system best, and easily accessible, since it resides as a machine representation. A model carefully constructed around this template will have an accuracy and validity far beyond models created by more traditional techniques.

Use the knowledge base insures that the model's structure matches the system's structure. The linkages and feedback relationships existent in the knowledge base are the driving mechanisms behind the system's behavior and are essential to any model designed to imitate that behavior. The knowledge base contains all the information necessary to describe the dynamic or time dependent character of the system; it is the fundamental resource in modeling the system.

KBSIM AS A MODEL PREPROCESSOR

Constructing a systems model from the template of the knowledge base requires extracting entities and relationships pertinent to the aspects of the system which are to be modeled. At the heart of the knowledge base is the implicit understanding that system entities are highly interconnected and that property produces the dynamic behavior of the system. This is the philosophical basis upon which any model making use of the knowledge base structure will reside. Models using the knowledge base are geared to understanding behavior via entity interrelatedness and the preprocessing techniques use d in KBSIM will extract information from the knowledge base according to the knowledge base structure.

The first step to building a system model is clarifying the purpose of the model, the scope of the model, and the criteria by which its accuracy will be evaluated. The stated purpose generally determines the scope of the model and the accuracy that must be achieved. Once the fundamental questions of building the model have been answered, they must be translated into the first order subsystems or variables that must be modelled. Figure 2 presents the procedure for selecting subsystems and significant variables for the model. Only an initial subsystem or set of variables must be acquired. KBSIM determines interactively the extent of the knowledge base that will be brought into the model. The number of included variables is a function of the linkages between requested entities and their system counterparts. Any combination of rank restricting searches can be used to uncover adjacent variables that are important to the structure of the system.

Primarily important to the system's time dependent behavior, feedback loops in the system and subsystem families are the principal items selected for model inclusion. Any system entity desired in the model is examined for its membership in a feedback set and the entire feedback set is summoned and presented in the preprocessing output. Decisions can be made on including the entire feedback set or only members of the set with functional relationships that recognize the nature of the feedback connection.

KBSIM uses the full repertoire of interrogation information to choose entities and linkages essential to a realistic model of the system. During KBSIM's preprocessing, recognize that system experts are, in effect, selecting entities and the relationships between them that will become the model. Every linkage between selected knowledge base entities exists in the linkage specification data. Every linkage specification must be encoded in the modelling language to produce a programmed model of the system. This encoding is specific to the modeling methodology chosen though KBSIM does provide preprocessing output of the form shown in Figure 3. This output speeds equation creation and organization. Just accessing the knowledge base reduces model development time and unquestionably enhances the validity and accuracy of the resulting models.

KBSIM AS A MODEL COMMUNICATOR

Models created from the dynamic structures represented in the knowledge base to describe system behavior must be communicated to those using the model output. Documenting and communicating models effectively has always been a difficult task. Providing users with the understanding of why a chosen set of variables and relationships approximates the system under study is essential

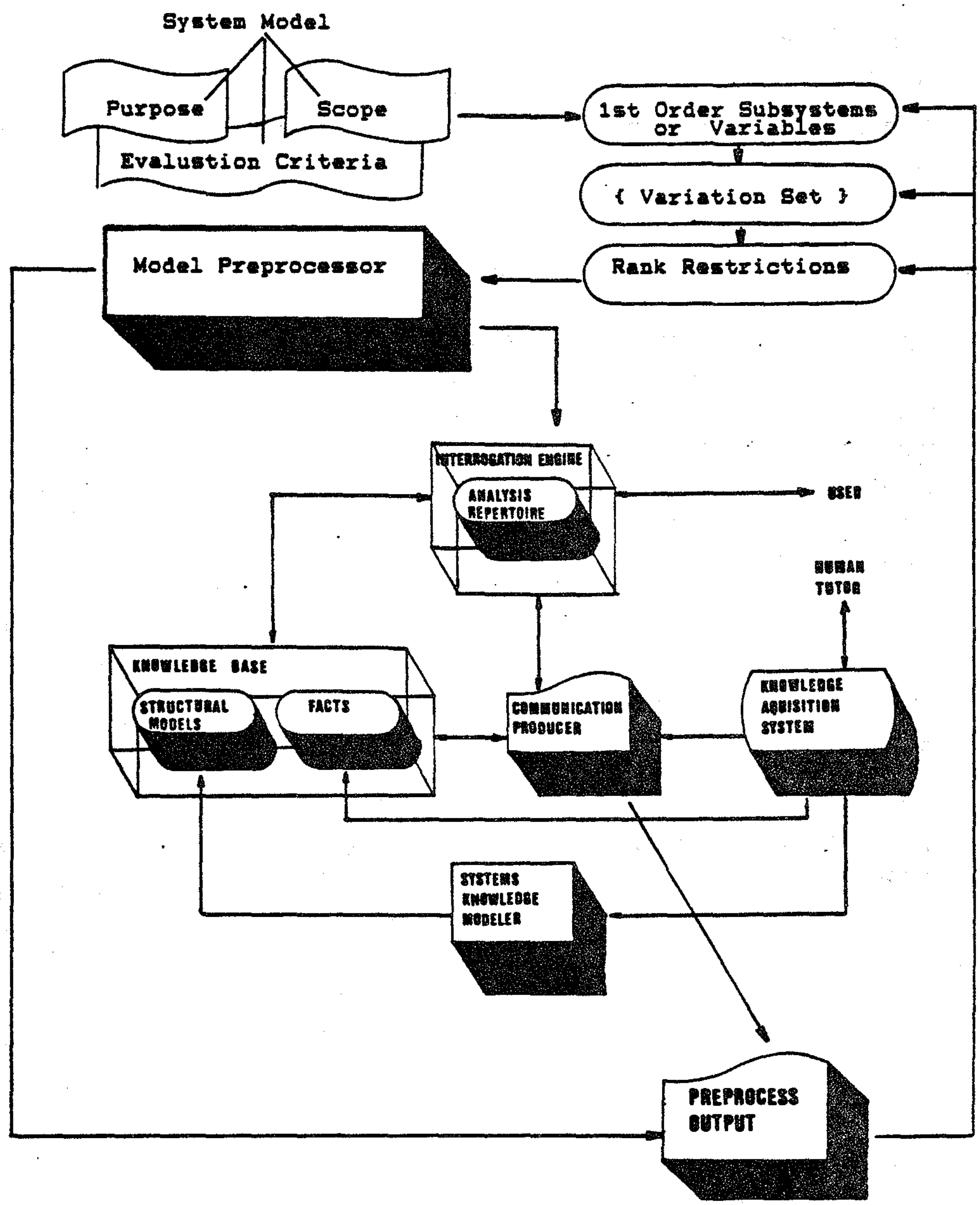

Figure 2 KBSIM in Model Preprocessing

document: MODEL EQUATION WORKSHEETS

subsystem: ENGINE IR SIGNATURE worksheet: v1
tutor: D.F. Young page: 1/2

Worksheets Using : Entity Acronyms

EIRS	=	EIRRC	EEPIRC	EHPIRC
TAIRI	=	EIRS FCIRDRF	AA TARPMIRR	BIR TAR
EHPIRC	=	ENWIRC	ETIRC	EFIRC
EEPIRC	=	ECSS	EEGT	
EEGT	=	EGM		
ECS	=	EES		
EGM	=	EES	EPRC	EJE
EES	=	input :		
ENWIRC	=	NWCC	IRAMCE	
ETIRC	=	TCC	IRAMCE	
EFIRC	=	FCC	IRAMCE	
EEFCIRC	=	EFCCC	IRAMCE	
EIRRC	=	ESSA		
EPCR	=	input :		
NWCC	=	input :		
TCC	=	input :		
FCC	=	input :		
EFCCC	=	input :		
ESSA	=	input :		
EJE	=	input :		
IRAMCE	=	input :		
TAR	=	input :		
TARPMIRR	=	input :		
FCIRDRF	=	input :		
AA	=	input :		

Page 1 of 2

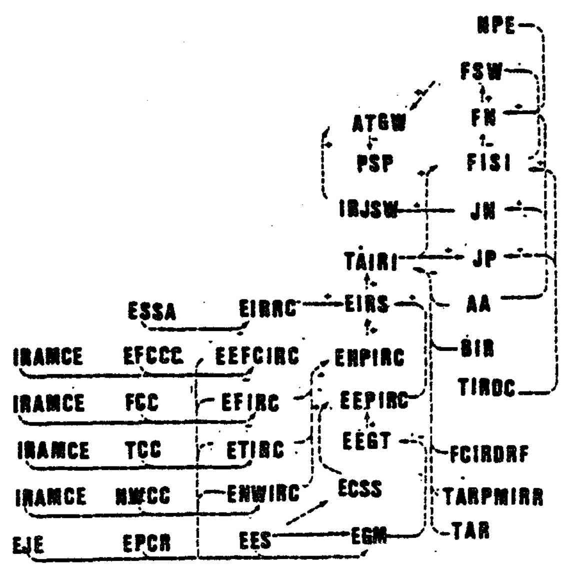

Figure 3 Preprocessing Output

if users are to believe and include model output in the decision making process. The modeler must know why equations in the programmed model are accurate symbols of the relationships in conceptual models of the system.

When models are built from the knowledge base, every entity and relationship can be documented from data included in the knowledge base. More significantly, the data describing model variables and linkages is provided by system experts. When KBSIM is sued as a model preprocessor, any equation set developed from the knowledge base can be directly supported by expert information using KBSIM documents. The variable set selected by the KBSIM preprocessor can be translated into a visual graph, a casual diagram, which describes the model based on that variable set. The model can then be supported in words, equations, and pictures. A complete package for communicating the structure of the model exists when the model is built from the knowledge base. Documentation is inherent to the model construction process when using KBSIM.

Persuading users of the model's validity becomes easier when they recognize that the model is only a translation of a subset of the knowledge base into a modeling language. Collected verbal descriptions can provide a narrative that highlights captive data and exposes the motivation behind any model equation. The users can understand the model and believe the model if they understand and believe the content of the knowledge base. The communication documents provided by KBSIM significantly reduce the cost and effort of supportive model documentation.

KBSIM AS A MODEL MANAGER

Systems modelling can be time and capital intensive. Many organizations react unfavorably to the concepts of modelling due to exaggerated claims about model capability and the overrun costs incurred by past modelling attempts. Implementation is often only a dream of those who are to use the model are seldom an integral part of its formulation. Managing the modeling effort can be a nightmare in coordinating and verifying equations and relationships, a problem enhances by the need to simultaneously educate a beckoning management about model building. Good model management aids in constructing the model in reasonable time frames, preparing the audience for using the model, establishing the model's validity, and educating management about concepts embedded in the model's structure. Tabs are kept on model progress and documentation is built concurrent with parameter identification, coding, and model execution.

KBSIM was discussed as a model preprocessor and communicator. Those activities are a fundamental part of model construction and management. But establishing validity and consistency remain time consuming aspects of model management. Much of what has been discussed about coordinating experts along lines indicated by KBSIM is useful in involving experts in model verification. The tasks of equation verification are expedited if the knowledge base contains equations for the linkage specifications. Verification is a matter of establishing that the equation is correctly translated into the modeling language. If the knowledge base lacks equations, appropriate experts can be contacted for the required information.

The preprocessing of the knowledge base can include construction of variable names for included knowledge base entities. A dictionary is built assigning a variable name to each entity; equations can be examined and dissected to check that they contain only and all entity linkages for a given variable. Generated equations can be submitted for consistency checking.

Since KBSIM coordinates entity and linkage documentation and the entity and linkage sets involved in the model, much of the documentation and information coordination burden is removed from the model management process. Additionally, since all necessary system elements to be included in the model are identified in the preprocessing activity, the progress of generating a set of model equations for the entire model can be monitored, unlike the normal experience in which the equation set grows exponentially as model building progresses and every time estimate or status report is invalidated. Traditional modelling enterprises always seemed to find "just a few more things" that should be included in the model. Validity and consistency changed daily as the model evolved from a fundamental set of relationships to an amalgam of every system entity to insure capturing the character of the system. Fortunately, KBSIM provides a tool to efficiently manage structured model development.

SUMMARY

Managing highly linked technology systems for change and efficiency is a formidable task. The objectives of strategic management are to provide a coordinated program for integrating the outputs of subsystems in a way that produces the desired behavior of the overall system. This is impossible from the perspective of any subsystem. An understanding and accessibility of the entire system to an expert level of detail will allow good decisions and realistic plans providing the ability to engineer change in an existing system. The only way to ensuring that the full scope of system expertise is incorporated into a decision or management activity is through a system knowledge base.

Near and long term system concerns can be attacked through manipulating the knowledge base or modelling some subset of the knowledge base. Models generated from the system knowledge base have a fundamental soundness to their structure and can be constructed, communicated, and managed efficiently using KBSIM. Many strategic decision require models of the expected system behavior under a projected future environment. The model and its strategic use are natural outgrowths and capabilities of an interrogation machine operating on a carefully built knowledge base.