Proceedings of the 1996 Winter Simulation Conference
ed. J. M. Charnes, D. J. Morrice, D. T. Brunner, and J. J. Swain

ENTERPRISE MODELING WITHIN AN ENTERPRISE ENGINEERING FRAMEWORK

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ABSTRACT

The role of abstraction, or modeling, is a major element in Enterprise Engineering. Enterprise engineering deals with the analysis, design, implementation and operation of an enterprise. The Enterprise Engineer addresses a fundamental question: "how to design and improve all elements associated with the total enterprise through the use of engineering and analysis methods and tools to more effectively achieve its goals and objectives". This paper describes a describes a multi-view reference architecture for modeling an enterprise. It presents a modeling scheme under development which supports the architecture and acts as a tool for Enterprise Engineering.

1 INTRODUCTION

Enterprise Engineering is the body of knowledge, principles, and practices having to do with the analysis, design, implementation and operation of an enterprise. In a continually changing and unpredictable competitive environment, the Enterprise Engineer addresses a fundamental question: "how to design and improve all elements associated with the total enterprise through the use of engineering and analysis methods and tools to more effectively achieve its goals and objectives".

There are several world view assumptions present in enterprise engineering. The first assumption is that the enterprise can be viewed as a complex system. This is necessary because systems in organizations are systems of organized complexity. Complexity is the result of the multiplicity and intricacy of man's interaction with other components of the system. Secondly, the enterprise is to be viewed as a system of processes. These processes are engineered both individually and holistically. The final assumption is the use of engineering rigor in transforming the enterprise. The enterprise engineering paradigm views the enterprise as a complex system of processes that can be engineered to accomplish specific organizational objectives. In the Enterprise Engineering paradigm, the enterprise is viewed as a complex system of processes that can be engineered to accomplish specific organizational objectives. Enterprise Engineering recognizes the ever-changing organic nature of the enterprise, and therefore has a valid world view or paradigm (Liles et al. 1995).

These assumptions have implications in enterprise modeling. Models are abstractions of real life systems. Models are created to assist an analyst extract requisite details of the system in order to gain a better understanding of the complex system. An enterprise model is a symbolic representation of the enterprise and the things that it deals with. An enterprise model contains representations of individual facts, objects, and relationships that occur within the enterprise. According to Burkhart (1992), the description of these interactions is the basis for measuring how well the activities of the enterprise work together. The selection and design of enterprise processes for the effective cooperation is a prime objective of enterprise engineering. Enterprise models can assist the goal of Enterprise Engineering by helping to represent and analyze the structure of activities and their interactions.

This paper presents an enterprise modeling scheme which supports a process centered approach to the analysis and design of the enterprise. The scheme, currently under development, utilizes concepts of object-oriented and agent modeling techniques. An innovative feature of the scheme is the ability to present federated activity, process, business rule, organization, and resource views of the process. The paper will first discuss an enterprise modeling architecture which the scheme supports.

2 ENTERPRISE ARCHITECTURE

An enterprise architecture is a "blueprint" or "picture" which assists in the design of an enterprise. An enterprise architecture must define three things. First, what are the activities that an enterprise performs? Second, how should these activities be performed? And finally, how should the enterprise be constructed?

An enterprise is a collection of enterprise activities organized into a set of business processes which cooperate to produce desired enterprise results (Presley 1993). In the context of this paper, an enterprise activity is defined as any organized behavior which transforms inputs into outputs. It is proposed that enterprise activities are the basic building blocks of an enterprise and, furthermore, that enterprise activities become useful only when organized into business processes.

The architecture takes a systems view of an enterprise in which an enterprise is seen as a system which takes in inputs and produces outputs under some set of environmental constraints. Figure 1 shows several sets of enterprise activities (boxes) logically organized into business processes (shaded ellipses). The business processes are organized into an enterprise represented by the larger box. At this high level of abstraction, the enterprise itself is represented as a system which takes inputs and transforms them into output using available resources under the bounds of certain constraints.

The figure also shows the interaction of three process categories. It is proposed that business processes naturally fall into three categories: (1) those processes which transform external constraints into internal constraints, (2) those processes which acquire and prepare resources, and (3) those processes which use resources to produce enterprise results. In the figure, a category 1 process (BP8) takes constraints from the environment and through some process converts them into a set of constraints which will be used to constrain other processes. A category 2 process (BP7) likewise takes in resources from outside of the system and prepares them for use by a category 3 process (BP5).

An enterprise must be viewed from several perspectives if it is to be fully described and understood (Barnett 1994; ESPIRIT Consortium AMICE 1991). Previous work in the development of architectures by the Automation & Robotics Research Institute (Presley et al. 1993) describes a five view approach. The Business Rule (or Information) View defines the entities managed by the enterprise and the rules governing their relationships and interactions. The Activity View defines the functions performed by the enterprise (*what* is done) while the Business Process View defines a time sequenced set of processes (*how* it is done). The resources and capabilities managed by the enterprise are defined in a Resource View. Finally, the Organization View is used to define how the enterprise organizes itself and the set of constraints and rules governing how it manages itself and its processes.

This research proposes that unless all of these views are included, a comprehensive model of the enterprise is not possible. A comprehensive enterprise model addresses a major shortcomings of current modeling techniques: that of disjoint modeling of views. Traditional process modeling methodologies typically emphasize one aspect or view of an enterprise over others. Each aspect is modeled from vastly different

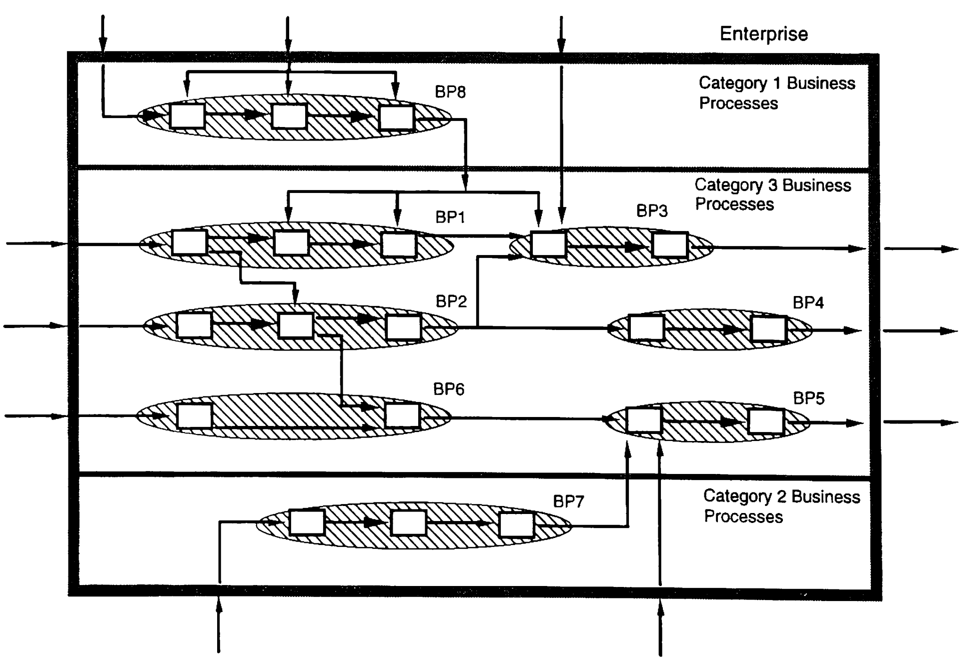

Figure 1: Enterprise as Collection of Business Processes

conceptual perspectives. Separation of the aspects of a business process into a number of separate models is an unnatural representation method. The distinct pieces of a business process exist and have meaning as a single unit.

This does not, however, mean that all these views must be present in all models. A model is an abstract representation of reality which should exclude details of the world which are not of interest to the modeler or the ultimate users of the model. Models are developed to answer specific questions about the enterprise. As long as the model answers the questions for which it was developed, only one or a few of these views may be sufficient.

3 ENTERPRISE MODELING SCHEME

In this section, the modeling scheme being developed to address the needs of the enterprise modeling architecture is discussed. The concentration of this research is on higher level enterprise processes, although the scheme is applicable at all levels of the enterprise. The model is developed by progressively specifying the five views, starting with the business rule view and ending with the organizational view. Feedback and refinement of previously defined views is accomplished to ensure consistency among the views.

The scheme is built upon the IDEF modeling methods (Mayer, Painter, and DeWitte 1992). IDEF is a suite of modeling methods which developed out of the Air Force's Integrated Computer Aided Manufacturing (ICAM) project in the 1980's. Each of the IDEF methods provides a set of modeling syntax and steps for describing a particular perspective of an enterprise. The IDEF suite provides for functional modeling (IDEF0), information modeling (IDEF1), data modeling (IDEF1x), systems dynamics modeling (IDEF2), process description capture (IDEF3), object oriented design (IDEF4), and ontology capture (IDEF5), among others. The modeling scheme being described makes use of IDEF0, IDEF3, and IDEF5.

A holon or agent based approach to identifying and representing the activities and resources is used. The term holon was first proposed by Arthur Koestler (Koestler, 1989) as the basic unit for modeling biological and social systems in his book *The Ghost in the Machine*. The term, according to Koestler, is intended to describe any entity which is at the same time "a whole unto itself, and a part of other whole(s)." Holons belong to structures which consist of self contained units capable of functioning independently but nevertheless are dependent on other units. This structure, called a holarchy, is a temporary assembly of holons which has a specific set of temporal goals and objectives. The strength of a holarchy lies in its ability to construct highly complex, resource efficient systems which are highly resilient to internal and external disturbances and are adaptable to changes in the environment. As can be seen, the structure of an enterprise can be considered to a holarchy.

3.1 Business Rule View

A business rule model identifies the objects of interest in a particular domain and their relationships. In this way, the business rule view is closely related to the concept of an ontology. According to Benjamin, et al. (1995), "an ontology is a description of the kinds of things, both physical and conceptual, that make up a given domain, their associated properties, and the relationships that hold among them as represented by the terminology in that domain". Within the IDEF suite, the IDEF5 ontology capture method (Benjamin et al. 1994) was developed for this purpose. It facilitates the collection of knowledge about physical and conceptual objects along with their associations. It provides facilities for diagrammatic representations of an ontology. In addition, a structured text language for detailed ontology characterization is present. Figure 2 shows a small part of a model for an enterprise. The circles represent kinds (roughly equivalent to class or type) with arrows representing relations. As can be seen both tangible things (Production Plan), concepts (Status) and activities (Support Production) can be defined as entities.

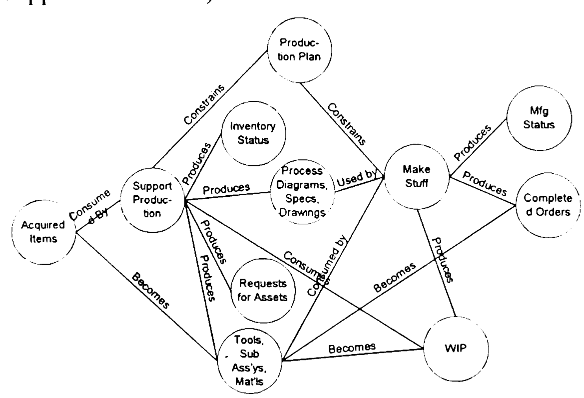

Figure 2: Partial Ontology Model

The ontology model can itself be thought of as the integrated model of the enterprise. The creation of this model is extremely important as the ontology model will form the basis for the other four views. Entities and relationships for all views are defined within the business rule view. Each of the views is built by extracting the entities and relationships particular to that view. This helps to ensure integration of the views and eliminates redundancy in building the views. For example, a resource entity is defined once. Properties and relationships for each view are progressively defined as the views are developed. Even as these new properties and relationships are defined, there will be only one instance and definition of the resource. This is contrasted to traditional techniques where the resource is defined in the activity view, redefined within an information view, etc.

The model is created through knowledge acquisition methods such as interviews and reviews of existing models and documents. The modeling scheme and method provides a limited set of modeling elements of predefined objects and relations for creating an enterprise model.

3.2 Activity View

An IDEF0 activity model is created based on the business rule model created in the previous step. IDEF0 is used to represent the functional (i.e., activity or process oriented) framework of a system. There are five elements to the IDEF0 functional model (see figure 3): the activity (or process) is represented by boxes; inputs are represented by the arrows flowing into the left hand side of an activity box; outputs are represented by arrows flowing out the right hand side of an activity box; the arrows flowing into the top portion of the box represent constraints or controls on the activities; and the final element represented by arrows flowing into the bottom of the activity box are the mechanisms that carry out the activity (Mayer et al. 1992).

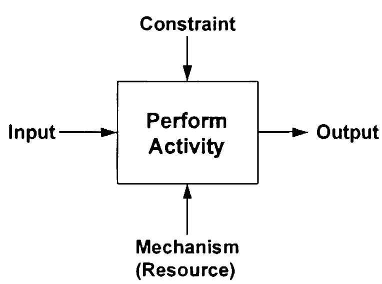

Figure 3: IDEF0 Representation

Another characteristic of the IDEF0 modeling technique is that each activity and the ICOMs can be decomposed (or exploded) into more detailed levels of analysis. This characteristic is especially useful in enterprise modeling where details about lower level activities can be captured, but at the same time, be hidden from models of the enterprise at higher, more abstract levels. This can be thought of as equivalent to the development of hierarchical simulation models.

The use of the IDEF5 model will enforce a level of structure to the standard IDEF0 process. The model is bounded by identifying what is to be included in the model. A process can be considered as a special relationship that exists among objects. In this scheme, however, processes are themselves defines as objects. This allows for the capture of additional knowledge and the ability make inferences about the processes. The identified processes are used to create a list of candidate activities. The objects and activities are defined in additional detail, with the scheme enforcing some properties which must be defined for the model. This will be done by defining a small core set of properties for activities, mechanisms, constraints, and objects manipulated by activities.

The identification and specification of the IDEF0 activities from the IDEF5 model is shown conceptually in figure 4. In this example, an activity called "Fill Orders" and the ICOMs associated with it are identified. The activity model created in this activity will be identical to a "standard" IDEF0 model which would show 3 to six such activity boxes and the interactions of the activities as defined by the flow of arrows among the activities.

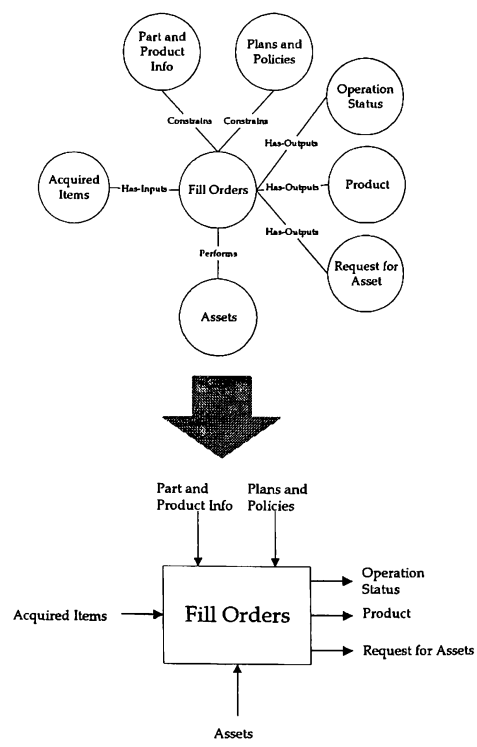

Figure 4: Deriving an IDEF0 Activity Box

At this point actual mechanisms are not identified, but rather, capabilities or kinds of mechanisms required are identified. As part of this activity the ontology specification for activity entities are updated. Properties defined include a description of the activity, and required capabilities.

3.3 Resource View

The Resource View defines two basic aspects: the resources necessary to accomplish activities (and therefore acts as a capability model), and how those resources are organized and "owned" by the organization. To form the resource view, actors and the process they perform are coupled, in essence forming the holons described earlier.

This coupling of entity and process allows for attributes and performance characteristics of interest to be represented in a more holistic manner. It is proposed that only when a particular process is assigned to a particular resource can the values of these performance characteristics be identified. This allows for increased reasoning to be applied. The assignment is done through user defined selection rules with the aid of available analysis tools. Once the agents to perform the activities are identified, the performance of the enterprise can be defined.

As with this the Activity View, the Resource View is built from the Business Rule View. Two classes are especially important here: Activity and Actor. Also important is the relationship of the two as expressed by attributes named Activity-Performance and Actor-Performance. Both of the performance attributes can be of two types: capability or actual performance. The performance capability required by an activity will be matched to the performance capabilities available in potential actors. These will be evaluated on a set of measures as determined by a decision maker to select the best alternative. Common kinds of performance include cost and cycle time.

There are many types of analysis techniques which could be applied. The goal of this research is to develop a modeling scheme to support both manual and automated analysis and design of enterprise processes. The ontology based approach is being pursued to specifically facilitate the use of automated reasoning tools. Automated analysis and design would be supported by advanced techniques such as artificial intelligence and simulation techniques, especially in the evaluation of resources and alternate ways of performing a process. The ontology based approach is closely related to object oriented methods of process modeling and analysis approaches described by several authors. In the area of simulation, for instance, Pratt, Mize et al. (Mize et al. 1992, Pratt, Mize and Kamanth 1993) describe an object oriented approach to building simulation models. The modeling method described here could be adapted or interfaced to work with such simulation approaches. The advantage to be gained is in the availability of a federated model from which various analysis techniques could be built.

3.4 Business Process View

This step creates the business process view for the actor described in the previous step. The business process view defines the time ordered sequence in which a process is executed. It essentially describes the behavior of the actor. The process view is not specified until the agent is defined because for the purpose of designing an enterprise, we are first interested in the activity view ("what is done"). Once that is defined, we are now interested in the behavior that allows for the activity to be accomplished. That is, knowing "what needs to be done?" for an enterprise, we are now interested in the "what can it do?" when selecting resources. The holon approach taken with this model in which each resource can perform an activity any way it seems fit, means that the "how does it do it" (internal behavior) is not of interest until the agent is defined. The behavior is defined by the set of internal processes used by the holon. For any agent, several process scenarios can be created. Examples include alternate ways of performing a process based on existing constraints, and the tracing of alternate inputs through the agent. The specification of the process model is accomplished by again examining the IDEF5 Business Rule Model. It may be necessary to develop additional IDEF5 submodels to define information which was not previously available. This process view is specified using the IDEF3 Process Description Capture Method (Mayer, Painter, and DeWitte 1992). The method consists of process flow diagrams and elaboration diagrams. One of the appealing aspects of IDEF3 is its relationship to the IDEF5 ontology capture method through the use of object state transition diagrams. Additionally, there are commercial tools available for the development of simulation models from IDEF3 process models. An example of an IDEF3 model for a process to ship a customer order is shown in figure 5.

3.5 Organization View

The organization view defines the reporting and constraint structures put in place to guide the performance of entities and activities. Both of these aspects is defined by examining the IDEF5 business rule model. A limited set of predefined kinds and relations are provided within the scheme to assist in developing this view. The modeler would, by identifying the instances of each kind, complete the model. The result of this activity is an Organization View specified in IDEF5. It is a simple matter to then display this information in a form familiar to the user, such as a standard organization chart.

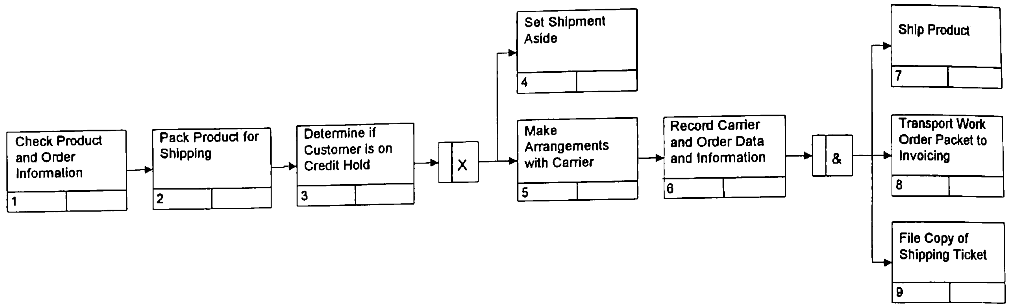

Figure 5: Example IDEF3 Flow Diagram

Many of the entities defined in the other views also participate in the organization view. However, several entities have been defined specifically to support the organization view. Included here are planning objects such as goals, plans, policies, and measures. The roles and positions agents in the enterprise play are identified. These are then linked to each other, activities, and planning objects through a set of management and organization links (Fox, Barbuceanu and Gruninger 1995).

4 CONCLUSION AND FUTURE DIRECTIONS

This paper has presented an architecture for modeling an enterprise and a representation scheme designed to support the architecture. The development of the representation scheme was guided by the need to facilitate both manual and automated analysis and design of enterprise processes. Research is being conducted into possible techniques with which the scheme could interface. The results of this research will provide a valuable tool for the modeling of enterprises.

Perhaps more importantly, this research is being conducted within the larger framework of the development of the discipline of Enterprise Engineering. A discipline has six basic characteristics: (1) a focus of study, (2) a world view or paradigm, (3) a set of reference disciplines used to establish the discipline, (4) principles and practices associated with the discipline, (5) an active research or theory development agenda, and (6) the deployment of education and promotion of professionalism (Liles et al. 1995). This research is furthering the goal of developing a tool for the application of the principles and practices of this emerging discipline. It is also a component of the active research program being conducted by the Automation & Robotics Research Institute in Enterprise Engineering.

ACKNOWLEDGMENTS

Research for this paper is funded in part by the National Center for Manufacturing Sciences, the State of Texas Advanced Technology Program Grant 003656-036 and by the National Science Foundation sponsored Agile Aerospace Manufacturing Research Center.

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