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An Overview of Manufacturing Enterprise Modeling and Applications for CIM Environment

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Abstract

The proposed works focus on concept of enterprise models and their significance in the implementation of CIM, by providing a complete, common, and correct understanding of the enterprise. The need for concentration on product model, process model and database for manufacturing Knowledge ahs been highlighted for the modelling of manufacturing enterprises. Further, a plan to develop an object-oriented model to represent and integrate the manufacturing enterprise operations has been presented.

Keywords: Enterprise Modeling, CIM, Object Oriented Approach and Enterprise Integration

1 Introduction

The major business challenges for today's manufacturing enterprises are: time-to-market, global competition, continuous improvement, and the integration of

business processes and information which focus on the management of change. To be in competition companies must be able to implement new production strategies rapidly and predict how change will affect their operational constraints. Active management of change is the most significant future requirement for enterprise operation.

The key to achieve these goals is the 'agility'[1] which implies to continuously monitor market demand, quickly respond by providing new products, services and information, quickly introduce new technologies and quickly modify business strategies and methods. The requirement for achieving agility is the greater integration between the functions within the enterprise and between the enterprises.

Information Technology (IT) has made available to the manufacturer [2] tools which can greatly improve the reaction to a new market situation, to speed up design of a product, to improve process planning, to maximize resource scheduling, and to stream line the production flow through a factory. Due to the rapid advances in IT, new paradigms that have successively emerged are CIM, JIT, lean manufacturing, Concurrent Engineering, and more recently Networked Enterprise.[3] Among these Computer Integrated Manufacturing (CIM) represent the direction in which the modern industries are moving

Computer Integrated Manufacturing (CIM) is the process of organizing manufacturing units under the control of a common information system to enhance their competitiveness [4, 5]. It is centered around the decisions regarding the planning and controlling of the data flow, data processing and data dissemination in a plant. In CIM since all the functions of the enterprise have to work together as an interrelated activities, a model is needed to identify the activities, data and resources related to CIM environment and to create the right relationship between them. Therefore, first step in the implementation of CIM is to achieve a complete, common, and correct understanding of the enterprise. Enterprise models are used to achieve this understanding. An Enterprise Model is an interactive representation of the organization, its processes, and resources. [6]

For the manufacturing enterprise, this model defines a unique set of business processes that are performed to design, plan, produce, and market the enterprise's products. It identifies following: what the enterprise does, who does it, how it is done, what resources are needed and available. However the most important aspect is how these elements relate to each other. Hence, enterprise modeling can be used to construct models of organizations for purposes of predicting and estimating the impact of change within an organization brought about by changes in the external environment.

Unlike the other systems a real enterprise has very complicated data architecture. Most of the data will be held in large number of package systems, for which the details of data structure may be unknown and most data is duplicated across a number of systems, with significant variations in quality, format, and meaning.

The technique of object oriented analysis and design because of their direct liaison with the physical reality, the modularization and reusability they offer, appear highly promising for enterprise modeling and design.. In an enterprise model, objects represent the resources, processes, roles and responsibilities in an organization. Since object oriented approach permits to design the data structures such that they characterize the objects, which can communicate with each other through functions, they enable to present the integrated picture of an enterprise [7].

With this idea a research work has been identified to develop an object-oriented model to represent and integrate the manufacturing enterprise that serve as an initial step towards implementing CIM. The current paper is a part of this work which focuses on some important issues on modeling of manufacturing enterprise.

2 Definition and uses of Enterprise Modelling

Vernadat [8] defined Enterprise Modeling (ELM), as the art of externalizing enterprise knowledge which adds value to the enterprise or needs to be shared. It consists in making models of the structure, behavior and organization of the enterprise. Ajit and Sadashiv [9] mention that an enterprise model neither implies an attempt to build a 'universal model' of an enterprise, nor is it capable of supporting all decisions, and define an enterprise model as an abstraction of an enterprise that is capable of supporting decision making across the functional boundaries within an enterprise. It is a decision support tool capable of modelling interactions between the various units of the business enterprise.

It is clear that, a common understanding of the enterprise is critical for any improvement effort. Modeling is an approach to providing a common understanding of the enterprise and how to achieve its desired future goals [10]. Following are the common uses of enterprise models [11, 12]:

- Facilitating human understanding and communication,
- Supporting process management and improvement
- Providing process guidance and Automating execution
- Facilitating the control of the real world process.
- Supporting the Decision Making

3 Contents and views of Enterprise Model

The Manufacturing Enterprise Model is a general description. There may be many unique variations to the model. Enterprise personnel operate the enterprise by creating the desired culture, integrating and improving processes, and implementing pertinent technologies in an optimal manner according to an implemented strategic plan. [13]

Lim et al [14] have provided a concise description of topics associated with Enterprise Modeling and integration by classification using seven key categories:
1. Drivers – Why is enterprise Integration required? ; 2. Goal – The aim to be achieved by applying the concept of Enterprise integration. ; 3. Domains – The main domains and components which have to be integrated in order to achieve Enterprise Integration. ; 4. Types – The different kinds of Enterprise Integration. ; 5. Modeling – The process of producing abstractions about the element relating to the operation of a business in order to understand the complexities in implementing Enterprise Integration. ; 6. Scale – The level of complexity involve in implementation of Enterprise Integration. 7. Issues – The barriers limiting the implementation of Enterprise integration.

According to Vernadat [3] an integrated manufacturing environment is essentially made of resources, applications, and information systems operated by humans or computers to produce products and services according to predefined business processes. A CIM environment is further characterized by inter-related information and physical flows governed by control flows. Things to be modeled and integrated therefore include: 1) Product information, 2) Business Processes 3) Technical Resources 4) Information 5) Organization and Decisions 6) Humans 7) Costs as financial flows.

For reasons of simplification, and to reflect different characteristics, it is convenient to consider the models from different views [1] such as, Workflow view, defining and describing the workflow through the production system. Resource view, defining and describing the human and physical resources in the system, Organizational/decisional view, defines the decisions and decision-making structure in the total organization of the manufacturing system.

Enterprise modeling for Computer Integrated Manufacturing Information System (CIMIS) architecture proposed by Ojelanki et al [15] consists of a three phase process.
(1) Requirements Definition, called business modeling;
(2) Conceptual Design; and
(3) Technical Design.

In the requirements definition phase, the focus is on defining the role which the system must play in supporting the manufacturing enterprise. The Information it must provide and its organizational context are defined via the modeling process. The conceptual design phase specifies the specific information (reports, screens, etc.) to be provided in support of the various work activities, the information processing procedures (Application Model), and the database schema and definition of subject databases. The Data, Database, and Application models are developed in this phase. The Technical design phase is concerned with identifying and analyzing different technological options for implementing the CIMIS

An enterprise model is expected to describe following [10]:

3.1. Three fundamental types of flows within or across enterprises:
- Material flows (physical objects such as products, tools, raw materials);
- Information flows (documents, data, computer files); and
- Decision/control flows (sequence of operations).

3.2. Five modeling views:
- Function view: addressing enterprise functionality (what has to be done) and enterprise behavior (in which order work has to be done);
- Information view: addressing what are the objects to be processed or to be used;
- Resource view: addressing who or what does what;
- Organization view: addressing organization units and their relationships, i.e., who is responsible for what or whom; and
- Business rule view: addressing all the constraints or rules.

3.3. Three modeling levels:
- Requirement definition: to represent 'the voice of the users,' i.e., what is needed, expressed in a detailed and unambiguous way;
- Design specification: to define formally one or more solutions satisfying the set of requirements, to analyze their properties and to select the 'best' one; and
- Implementation description: to state in detail the implementation solution taking into account technical and physical constraints.

3.4 Integration problems

Enterprise modeling should focus on following integration problems; i) Integration between design and manufacturing, ii) Integration of markets, iii) Integration between several development and manufacturing sites, iv) Integration between suppliers and manufacturers, and v) Integration of multi-vendor hardware and software components [3].

4 Enterprise Modelling Architectures AND Approaches

Enterprise modeling approaches can be grouped in to following categories [16-18]

a. Modeling of Enterprise information system; this approach concentrate on modeling the life cycle of enterprise information system and mainly concerned with IT resources.

b. Modeling of enterprise entities and activities; this approach concentrate on modeling the life cycle of enterprise functional entities and activities, extending from concept creation to maintenance.

c. Enterprise ontology modeling; this approach assumes that effective communication can only be made possible through shareable concepts and their representations and

shareable knowledge.

d. Object oriented approach : An object oriented approach consist of object, where each object represents a physical entity, a concept or any aspect of interest to the data based applications The fundamental idea behind this approach is to combine in to a single unit both data and the functions that operate on that data. Such a unit is called an object. The positive aspect of this approach is the match between programming objects and real world objects.

Another key concept regarding enterprise modeling is called the 'generic enterprise model'. [19]. Generic enterprise modeling involves creating a generic model capturing commonalities among individual real world system and instantiate the template with specific Symantec derived from individual systems.

The complex features of enterprise cannot be defined in one single model. For this a set of models is used to describe an enterprise. The integration of these models is termed as enterprise architecture. There are two well-known types of architecture; reference architecture and a particular architecture. The former refers to a detailed collection of common attributes management and automatic control tasks and the functional necessities. The latter is the instantiation of reference architecture.

A key function of reference architecture for enterprise creation, operation, and analysis is to determine, in specific and generic ways, what characteristics of an enterprise are necessary to analyze to help achieve an improved degree of enterprise integration [20]. It is a body of rules that define those system features which directly affect the manufacturing environment into which the system is placed. These features include system configuration, component locations, interfaces between the system and its environment, and mode of operation.

Numerous reference architectures that have been proposed in the literature and the most important that are related to the current work are discussed briefly below. [19-26]

4.1 ARIS

Professor W.A. Scheer, University of Saarbrücken, Germany developed ARIS, 'Architecture for integrated Information Systems' designed to be used as a foundation for the creation and evaluation of methods for information systems design to support CIM environments. The components of an information system to be described from the business economics standpoint are conditions, events, processes, human labour (employees), equipment, production materials, and organizational units.

4.2 CIMOSA

The Computer-Integrated Manufacturing Open-System Architecture (CIMOSA) aims at elaborating open system architecture for Computer-Integrated Manufacturing (CIM) and defining a set of concepts and rules to facilitate the

building of future CIM systems. It defines an integrated methodology to support all phases of a CIM system life cycle.
To fully model specific aspects of the organization, CIMOSA defines four views:
a) The Function View b) The Information View c) The Resource View and d) The Organization View**.**

The enterprise function consists of three major parts: (1) the functional part (which captures the objectives and constraints as well as the relationship between input and output), (2) the behavior part (which captures the dynamic section of the enterprise function such as procedural rules for flow of control), and (3) the structural part (which specifies the relationships among different levels of decomposition within a given enterprise function).

4.3 EMS

The Enterprise Modelling System (EMS) has been jointly developed by the Institute for Advanced Manufacturing Technology and SIMCON, a consortium of companies engaged in collaborative research with the National Research Council of Canada. The main objective of EMS is to provide a comprehensive set of tools for the creation of structural and process models of the business and production operations within an enterprise, with capabilities specifically aimed at continuous process improvement and evaluation of decision-making alternatives.

4.4 GERAM

The Generalized Enterprise Reference Architecture and Methodology (GERAM) define a set of concepts for designing and maintaining enterprises during their entire life-history. It aims at organizing the existing enterprise integration knowledge. The framework has the potential for application to different types of enterprises. The coverage of the framework spans products, enterprises, enterprise integration, and strategic enterprise management.

4.5 GERA: Generic Enterprise Reference Architecture

It defines the enterprise related generic concepts recommended for use in Enterprise Engineering and integration projects. GERA is the most important component of GERAM.
The concepts can be categorized as, Human oriented concepts, Process oriented concepts and Technology oriented concepts

4.6 M*OBJECT

M*OBJECT, developed at the University of Turin, Italy, is a methodology for information system analysis, design and implementation for CIM. M*OBJECT covers all the three major phases in organization modelling, namely organization analysis, conceptual design, and implementation design. Although M*OBJECT focuses on the information system aspect, its methodology heavily emphasizes organization modelling.

4.7 GRAI/GIM

The GIM (GRAI Integrated methodology) developed by the GRAI laboratory at the university of Bordeaux provides a global model, a modelling framework and a structured approach to guide the application of the methodology. The global model describes the invariant parts of the CIM in terms of subsystems relationships and behaviour. According to the global model is based upon the concepts of three activity types and their corresponding subsystems. The physical sub-system which, performs the activities of product transformation using human and technical resources.

4.8 PERA

The PERA (Purdue Reference Architecture) methodology defines a generic information system in terms of manufacturing tasks and human based tasks. The methodology was developed in order to assist in modeling computer integrated manufacturing enterprises. Its success lies in its ability to develop an overall view of the two categorized tasks (manufacturing, human) and the interdependencies between them.

4.9 The TOVE Methodology

TOVE (Toronto Virtual Enterprise) is an ontological approach which aims to create a common and shared terminology in an enterprise. TOVE defines the meaning of each term (semantics) in an easy to understand, and describes these semantics as a set of axioms. TOVE finally defines a set of symbols for depicting a term in a graphical form. According to all of the attempts to create a general enterprise model fail to produce a set of criteria against which knowledge representations can be evaluated.

5 Object Oriented Approach

The object oriented concepts not only encourage the use of modern software engineering principle, but also promote and facilitate reusability through mechanism

of class hierarchy [27]. These concepts permit us to treat the entities such as machines, materials, people, concepts, scheduled, models etc as objects. A manufacturing system is a very complex network of physical activities, decision making and information flow. Most manufacturing facility contains information bases which are independently designed. In such an environment improvement in manufacturing performance can be obtained by sharing data in manufacturing complex. An approach to this end to built a knowledge base architecture which can incorporate existing heterogeneous databases with non-conventional data types such as object oriented database [28, 29]. The following are some significant contributions on application of object orientation approach for modeling and integration of manufacturing organizations [27-35].

Bakalem et al [30] have proposed an integrated methodology to simulate manufacturing system which includes a static modeling approach using an object oriented technique in the initial stage. This approach is based on some classes to model the physical and logical behavior of the system. It is followed by a dynamic modeling approach. The proposed work also presents a draft of library of object classes dedicated to manufacturing system simulations. Livesly [31] has presented an approach to object a system design in an integrated environment by claiming the following benefits; robustness, flexibility, expansibility and maintainability. By using an object environment enterprise resources have been presented as virtual models. Marcos et al [32] proposed that manufacturing systems can be considered as being a collection of objects (machines, people, data etc.) supported by a complex set of software systems communicating in a structured or semi-structured manner to achieve a manufacturing goal and described a CASE environment which provides structured support for resource modelling based on object orientation. Murgatroyd et al [33] have identified requirements for modelling resources to support the analysis of manufacturing enterprises. The resources have been viewed as set of manufacturing object abstractions comprising encapsulated state and behavior with attendant visible services. These classes represent the minimum information require to build applications. Sai Peak Lee et al [34] have pointed out that the varied nature of manufacturing systems which is wide, dynamic and complex are obstacles in manufacturing software development and proposed a solution to solve these problems by developing a object oriented manufacturing framework with a set of integrated reusable components. Wand et al [35] described an approach for creating a general object oriented information system model from an object oriented enterprise model based on ontological foundations. They have introduced the concepts of delegate and static objects and applied in Telecommunication Company.

Object oriented approach offers number of important advantages for representing real world data. Some important advantages are [17]; inheritance (one object inheriting the properties of other objects), data abstraction (data and the functions operating data are defined within an object, hence any changes are localized) reusability (an object can used a number of applications), rich in

representation (objects include both data and methods and hence represent to behavior as well as structure of the object), ease of simulation (objects communicate by means of massages).

6 Ontologies for Enterprise modelling

Ontology includes a vocabulary of the terms and some specification of their meaning. The ways the vocabulary is created varies. Some vocabularies are highly informal. Others are semi-informal, and expressed in a restricted and structured natural language form using symbols and other notations. The purpose of every ontology related to enterprise modelling is to support integration within the boundaries of the enterprise by making available a common knowledge representation [35]. This maximizes the communication potential and, on the other hand, minimizes ambiguity and misunderstanding.

7 Proposed Work

The available literature revels that considerable work has been carried out or in progress and some reference architectures have been reported. However majority of the reported works have concentrated mainly on information flows and related databases. For the manufacturing industries, the product data, process data and the knowledge base related to manufacturing activities play a significant role in the automation of manufacturing activities. There is a need to develop a manufacturing enterprise model concentrating on the above three aspects, which will support in achieving the automated integration or interfaces of integrating i) Marketing and Product Design and development activities, ii) Product Design and Manufacturing Planning, iii) Manufacturing Planning and Production Planning such as purchasing, scheduling and routing etc. These automated interfaces are necessary for the realization of CIM.

To achieve the expected automated integration of its various activities the architecture of the Manufacturing Enterprise will be represented through the following models:

1. Organization Model to define structure, mission, vision, objectives and policies of the enterprise.
2. Product Model to present all characteristics from technical and marketing point of view.
3. Process Model to define basic processes employed in the enterprise.
4. Resource Model to define human and machinery and related equipments.
5. Information Flow Model: to describes the flow of information between

various resources, processes and various part of the enterprise.

6. Knowledge base Model: to describe the overall manufacturing knowledge employed in the enterprise model.

The proposed enterprise models for the manufacturing industry are described in terms of the following basic business activities: marketing, business and manufacturing strategies, resources management, product design and development, production planning, manufacturing operations, quality management, customer delivery and post delivery services. The major constraints are: i) external environment; Govt. policies, taxation, state of economy, etc., ii) supplies and supplier relations, iii) competitors and iv) changes in technology and manufacturing philosophy.

In the organization model the organization is represented in terms of goals and levels. Each level consists of designated positions and each designated position is represented primarily in terms of a qualified person, functions, responsibilities and recourses. The product data involves the technical specifications of the product, specifications for manufacture and development, and the types of materials that will be required to produce the end product. The product model is represented in the form of bill of material and every component shown in the bill of material is represented by a geometrical model in terms of its manufacturing features, plain surfaces and tolerances.

A business / manufacturing process is a collection of operations / activities designed to produce a specific output for a particular customer or market. A process is thus a specific ordering of work activities across time and place, with a beginning, an end, and clearly defined inputs and outputs: a structure for action. Resources help to produce goods which have economic value. Resources model defines each resource by specifying their characteristics and utility.

Object oriented approach offers number of important advantages for representing real world data. Products, processes, recourses, organizational functions, various useful concepts used in manufacturing industries and organization itself are expresses in object classes. The concept of link of this approach can be used to describe the explicit relationship among classes of objects. The objects developed will be supported by ontological foundations. Some typical classes of objects are described below through their structure.

Structure of designated Position
(level, qualified person, set of functions, responsibilities, resources used).

Structure process
{ Goal, organizational units involved, specific inputs, specific outputs, resources (human and machinery), A set of operations that are performed in a pre defined sequence, costs, Addition of some value for the immediate customer (internal or external))

8 Conclusion

Enterprise integration has not yet become the common industrial goal or the specific day-to-day operational tool in the manufacturing community. CIM which represent the direction towards which current manufacturing industries are moving can only be realized if suitable model of the enterprise that support automation of all the activities of enterprise is made available. Lean enterprises, business re-engineering, concurrent engineering, and management of change - identified as current management concerns should be viewed as subsets of enterprise integration.

Working in this direction, the proposed research work has explored the concepts of enterprise models and their significance and also presented an outline of plan to develop an object oriented architecture representing the manufacturing enterprise which serves as an initial step towards implementing CIM

This architecture will address the details of the business process areas, which are already identified in the previous section in order to provide a complete and precise model of the manufacturing enterprise. The work is in progress in this direction and outcome will be reported later.

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