E-R Approach to Distributed Heterogeneous Database Systems for Integrated Manufacturing

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A critical step towards computer integrated manufacturing (CIM) is the integration of computer-aided design (CAD) and computer-aided manufacturing (CAM). Well developed CAD, CAM, and Business data processing systems generally exist in an organization. These systems represent years of work and very large investment for the organization. Thus a necessary condition for integration is defining schemes through which existing engineering and non-engineering data can be represented and manipulated in an integrated way. In this paper a Common Data Model (CDM) approach to distributed heterogeneous database is adopted for CAD/CAM integration and an Extended-Entity-Category-Relationship (EECS) Model (an extension of ER model) is proposed. The use of EECS model as a common conceptual data model for representing engineering and non-engineering data is discussed.

Databases have been recognized by the CAD/CAM community as an ideal medium to integrate isolated “Islands of Automation” and to speed up communication among different design manufacturing and business related software packages. This can increase the consistency of the data and can avoid costly data conversion.

In a manufacturing organization different functions require different data types. Graphical and geometrical data are generated during drafting and engineering design process. These data are represented and stored using entities and data structures suitable for displaying graphical images or for constructing mathematical models of parts for further analysis. Engineering data are generated and used by analysis packages such as structural and thermodynamic analyses, simulation of motion, and material flow. Each analysis package has unique requirements for data input and output. Most manufacturing data takes the form of a procedural plan or sequence of actions. Textual data are found in all phases of integrated manufacturing from design through marketing; however, the heaviest use is in managerial applications such as production scheduling, cost estimation, quality control, inventory control, sales and marketing.

Thus in an integrated manufacturing environment the problem of heterogeneity has to be accepted and dealt with at the hardware and software levels. The strategies such as standardization and top-down system building even though relevant are not capable of resolving complexities raised by the simple fact that design-manufacturing and business data processing systems were available only from different hardware and software vendors. Thus existing CAD, CAM and Business data processing systems in an organization are generally heterogeneous in terms of hardware and software. These systems represent years of work and very large investment for the organization. However awkward the situation might be, the solution is in defining schemes through which existing engineering and non-engineering data can be represented and manipulated in an integrated way.

The concern here is to define a framework that maps data from one representation dictated by a specific DBMS to another. Clearly, the basic requirement is that the mapping should not affect the intrinsic value of the data. The prevalent approach for implementing this mapping is to define a common data model (CDM) at the global level (Bernhardt & Johnson, 1983). CDMs are used in

Honeywell’s DDTS (Devor and Weeldreyer, 1980) and Computer Corporation of America’s MULTIBASE distributed architectures as global mapping schemes (Landers and Rosenberg, 1982). This paper presents an extended Entity-Category-Relationship model (an extension of E-R model), to define a conceptual schema for representing engineering data in a distributed, heterogeneous, design-manufacturing environment.

**Engineering Data Management**

The principal motive for considering engineering data (ED) as a self-contained category is the obvious inability of current DBMSs to effectively, let alone efficiently, accommodate design-manufacturing data. Engineering Data stems its differentiation from a number of well-celebrated qualities (Buchman, 1984; Koriba, 1983). They are generally complex, i.e., multiple entities are required to describe a basic object. This feature of engineering data calls for complex data structures capable of handling objects and their attributes. Another characteristic of engineering data is object composition. It indicates that a hierarchy of basic objects contribute to the object at the root of the tree. Additionally, more than one composite object is expected to use lower-level objects as building blocks (e.g., a certain curve could be in a number of composite objects).

The above two characteristics identify the lack of adequate data types to represent engineering data in existing database setting, hence, the rejection of off-the-shelf DBMSs as a means for managing engineering data. The deficiency in current DBMSs has resulted from the fact that present data models were conceived, designed, and implemented not particularly for the CAD/CAM environment. Thus, one may need to extend them (by introducing new more powerful data types), mix them (by using relational-network structures as in the IPIP [Bernhardt and Johnson, 1983]), or introduce totally new models that serve the strengthening trend of using computer-based systems in design and manufacturing.

Stonebraker, et al. suggested abstract data types and abstract indices (1983). Johnson et al. described a network-relational system to provide for the hierarchical nature of engineering data by viewing an engineering structure as a single entity called structured entity (1983). This architecture gracefully accommodates complexity and composition of engineering data. Lee and Fu designed a recursive and nondeterministic data model for handling engineering data (1983). Their approach is based on the aggregation and generalization concept of Smith and Smith (1977). This model is conceived to resolve issues related to complexity of engineering objects. Haynie (1981) proposed a network-relational hybrid data model. In their work, the relational model is used to store data regarding objects in the database; and network schema is used for managing composition of objects.

Recently the use object oriented model is advocated for CAD/CAM data bases. Cammarata(1986) developed an object oriented data model (ODM) for representing engineering data. A prototype implementation of the model was also developed. Kim et al.(1989) have built a prototype object-oriented database system called ORION which supports functions required by applications from CAD/CAM, artificial intelligence, and office information systems. The functions supported by ORION include change notification, composite objects, dynamic schema evolution, and transaction and query management. Object oriented approach has also been used for VLSI/CAD design (Gupta, et al., 1989).

The object oriented approaches and the implementation of DBMS’s based on this model works well in the situation where a new system is designed from scratch. They do not offer a solution to the problem of integrating existing heterogeneous systems.

The above citations, albeit incomplete, represent the general trend of either extending data models as a means for building DBMSs that are more suitable for handling engineering data and more efficient in satisfying their requirements or developing new data models. Detailed review of engineering data requirements can be found in Buchman, 1984.

**Distributed Database Architecture for Integrated Manufacturing**

Traditionally, Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) were treated as self-contained systems. Also the administrative systems supporting inventory control, purchasing, sales, etc. are generally developed and managed as separate systems. The rapid evolution of Computer-Integrated Manufacturing (CIM) Systems makes the coupling of these long-separated software systems essential (Halevi, 1980). The major obstacle to such integration is the theoretical and technological base that is necessary to guide its implementation. Also since existing CAD, CAM, and business systems represent years of work and large investment for the organization any approach to integrating them must protect this investment.

Distributed system technology can be used for linking various systems to accelerate the integration. In these systems communication network provide the physical means for connecting the dispersed systems serving different phases of manufacturing, and a heterogeneous distributed database management system provide an integrated view of the data. However, many issues related to data representation and mapping needs to be resolved. The concern here is to develop an approach for managing and integrating engineering data that reside at various sites managed by different DBMSs such that they can be collectively manipulated to satisfy global queries.
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