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 a 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 EECR 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 processes. 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 en-
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 a 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 MULTI-BASE 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 DBMS 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 (Stonebraker, Rubenstein, and Guttman, 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 (Johnson, Schweitzer, Warkentine, 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 (Lee and Fu, 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
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