Extending IDEF1X to model fuzzy data

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IDEF1X has provided a formal framework for consistent modeling of the data necessary for the integration of various functional areas in computer integrated manufacturing (CIM). The basic idea has been extensively applied in current manufacturing industry. Imprecise and uncertain information, however, is generally involved in many engineering activities. It is especially true for constructing intelligent manufacturing systems. This paper provides extensions to the IDEF1X, which makes it possible to represent fuzzy information.

Keywords: Data modeling, IDEF1X, fuzzy data, fuzzy IDEF1X, fuzzy data modeling

1. Introduction

Current manufacturing industries are typically information-based enterprises and computer technology has been involved in nearly all aspects of manufacturing. Computer integrated manufacturing (CIM) is a natural outgrowth of the evolution of computer inclusion in manufacturing activities. CIM reduces design costs, the in-shop time of a part and scrap, increases productivity, and provides many other benefits (Kusiak et al., 1997; Rembold et al., 1993).

Integrated computer-aided Manufacturing (ICAM), led by the United States Air Force and conducted from 1978 to 1983, is a significant project in computerized manufacturing in the United States. The objective of the ICAM project is to promote the development of integrated manufacturing systems, particularly in the aerospace industry (Doumeingstus et al., 1992). ICAM has resulted in several methodologies such as IDEF0, IDEF1/IDEF1X, and IDEF3, which are respectively applied for building functional models, data models, and process models.

During the past decade, some researches have focused on the use of IDEF tools (Ang and Gay, 1993; Chadha and Fulton, 1991; Doumeingstus et al., 1992; Kusiak and Zakarian, 1996). There have also been researches on the IDEF1X methodology (Deuel, 1993; Wichmann, 1990). A thorough treatment of the IDEF1X method may be found in (SofTech, 1981; Wizdom System Inc., 1985). The use of the IDEF1X methodology to build a database for multiple applications is addresses by Kusiak et al. (1997). Briefer overviews of IDEF1X are presented in Loomis (1986) and Appleton (1986).

In real-world applications, it is known that information is often vague or ambiguous. Different kinds of incomplete information have, therefore, been extensively introduced and studied to model the real world. Engineering design and manufacturing is one of the examples where the issue of incomplete information makes sense. Product design, for example, is essentially a process of reducing the incompleteness in the description of the conceptual design (Ma et al., 1999). The method to deal with imprecision was proposed in Antonson and Otto (1995), Otto and Antonson (1994a) and Wood and Antonson (1992) for the preliminary engineering design and calculation. A fuzzy expert system in a CAD/CAM system for the preliminary design can be found in Francois and Bigeon (1995). Besides, the organization and production management of virtual enterprise put an essential requirement on its information integration. The studies mentioned were essentially based on their dedicated concepts and
methods. There is a research direction in the context of computer aided engineering to deal with information with uncertainty and imprecision in a more general way, i.e., data or database modeling (Ma et al., 1999).

Incomplete information can be classified into two aspects, namely, imprecise information and uncertain information (Dubois and Prade, 1986; Kliir and Folger, 1988). Intuitively, the imprecision is relevant to the content of an attribute value, and it means that a choice must be made from a given range (interval or set) of values but we do not know exactly which one to choose at present. The uncertainty is relevant to the degree of truth of its attribute value, and it means that we can apportion some, but not all, of our belief to a given value or a group of values. The modeling of information with imprecision and uncertainty in relational databases for engineering design and production management was reviewed by Li et al. (1998). In Otto and Antonssoon (1994b), the imprecise and uncertain information was classified into design parameters, performance parameters, noise parameters, and tuning parameters. Generically, these types of imprecise and uncertain information can be described by null values, partial/interval values, fuzzy values, and probabilistic values in order to apply data modeling technology (Ma et al., 1999).

In addition to model and manipulate fuzzy information in relational databases, currently, some attentions have been paid on information uncertainty and imprecision modeling in ER model (Zvieli and Chen, 1986), EER model (Chen and Kerre, 1998), IFO model (Vila et al., 1996; Yazici and Cinar, 1998), and object-based model (Bordogna et al., 1999; George et al., 1996; Gysseghem and Caluwé, 1998; Vila et al., 1996). Some extensions have been proposed in these semantic data models then to enhance their modeling ability. Recently, extending EXPRESS-G to model fuzzy information has also received attention (Ma et al., 2000b). Unfortunately, IDEF1X, being a crucial tool for modeling engineering information currently, however, has not the capability to model incomplete information. This motivated the authors to look into the extension of IDEF1X such that it would be able to model incomplete information, in particular, incomplete information represented by fuzzy variables.

The remainder of this paper is organized as follows. The basic knowledge about IDEF1X concepts, fuzzy set and the fuzziness in semantic data model is reviewed in the Section 2. The fuzzy information representations in IDEF1X model are introduced in Section 3. Section 4 concludes this paper.

2. Basic knowledge

2.1. IDEF1X concepts

Stemmed from the entity-relationship (ER) approach to semantic data modeling developed by Chen (1976), the IDEF1X methodology shares many of the same constructs proposed in entity-relationship models, namely, entities, attributes, and relationships between these entities (Kusiak et al., 1997). Hence, IDEF1X is most useful for logical database design after the information requirements are known and the decision to implement a relational database has been made.

It should be noted that although IDEF1X provides categorization relationship, it does not support the generic specialization/generalization relationship and aggregation relationship in object-oriented modeling. In addition, a key is used to distinguish one entity from another in IDEF1X. When more than one attribute or set of attributes serve equally well for individuating IDEF1X entities, one of them must be designated as the primary key and list all others as alternate keys. Explicit foreign key labeling is also required. That means that object identifications in object-oriented modeling are not supported by IDEF1X. Finally, some features such as class hierarchies, the methods, and the encapsulations in object-oriented paradigm are not supported by IDEF1X either. Therefore, IDEF1X is not well suited for non-relational system implementations. If the target system is not a relational system but an object-oriented system, IDEF1X is not the best method.

2.1.1. Entities

Entities are concrete things or abstract notions that can be distinguished one another and can be understood, e.g., people, car, parts, and machines. An entity is a class of real or abstract objects with the same characteristics. An individual member of the entity is called an entity instance. For example, Car is an entity while the car SANTANA 2000 is an entity instance.

Entities can be classified to be identifier independent and identifier dependent. For an identifier independent entity, each of its instances can be