A New STEP-based Product Information Model and Its Implementation Approach

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Abstract

Product data exchange and interfacing between different CAD/CAM systems are of great importance to the development of concurrent integrated design. In this paper, an integrated STEP-based production information model for mechanical systems is presented. First, an architecture of this system is established using a three-layer architecture (application, logic and physical layers) recommended by STEP, and a new information model using database implementation approach is defined using STEP's EXPRESS language. This model includes GIM (General Information Model), SIM (Structure Information Model), SCM (Shape Construction Model), PFM (Physical Feature Model), MIM (Management Information Model). Then, the database implementation method to information model is analyzed thoroughly, which include how to build data dictionary, how to transfer EXPRESS entity to base table in relational database and how to access product data in database. The information model and its application can make heterogeneous CAD system integrate more convenient.

Key words: Integration, STEP, modeling, information and knowledge sharing, SDAI, Implementation method, Database

1. Introduction

STEP was approved in 1994 as an international standard for product data exchange. Building upon the lessons learned from the previous standards such as the Initial Graphics Exchange Specification (IGES), The Electronic Design Interchange Format (EDIF), Data Exchange File or Format (DXF), SET, Verband Der Automobilindustrie-Flachen-Schnittstella (VDA-FS), STEP differs from its previous standards in the following aspects:

1) It provides a neutral format for product data exchange over the entire life cycle of a product, which extends from the realization of the need for the product through its decommissioning;
2) It enables access, use, and exchange of product data between information systems regardless of the kind of hardware and software.
3) It caters to different industries.

Information systems are widely used in organizations, large and small. One of their...
functions is to store design information, such as engineering drawings, in various kinds of CAD systems. However, the CAD systems often represent the data in different formats. For example, one CAD system represents a straight line by storing the coordinates of the start point and the co-ordinates of the end point. A second system represents the same line by storing its start point, direction, and length. This creates a problem: the information systems perform the same functions, but they use different languages. Most of us are familiar with talking to someone speaking a foreign language: we are unable to understand each other. The same is true when one information system is sending information to another system. They are unable to communicate.

In addition, information technology is developing very quickly. Both hardware and software are replaced or upgraded every few years. For example, if you had stored an engineering drawing on a 5-1/4 inch floppy disk, you can hardly find a computer to read it in 1998. Even if you store information on the latest system available, the system will surely be replaced by more advanced ones in the future. The IBM 386 was thought to be powerful not too long ago. Now it is hardly seen anywhere.

STEP was established to overcome the communication barriers not only between the present information systems, but also between the systems of the present with those of the future.

This paper provides an overview of the structure and content of STEP, a new information model with database implementation approach and its realization are put forward. The paper is organized as follows. In section 2, the level concept of STEP and implementation method are discussed shortly. In section 3, product modeling of database implementation method and the conversion method of the model is described. Implementation and some test results are discussed in section 4. Finally, Section 5 contains concluding remarks and a description of future work.

2. Review of STEP and its implementation method

2.1 Level concept of STEP

The whole STEP system is divided into three levels: application layer, logic layer and physics layer [1, 2]; their relations are shown as figure 1.

Application layer uses the method of IDEFIX to describe systematic function activity, its connection and application information model. Logic layer is used to convert universal information model into product data structure described in EXPRESS language. Physics layer is used to export and designate formalization demand rule and implementation mechanism. It is the file layout that described in data structure.

The information generated during one project is related to predefined data and concept definitions, which are themselves represented as a relational system of concepts, connected via specialization, part-of-relationships (partonomies) and aggregations.

An example for logical references across the information layers is given in Figure 2. Product models with a high degree of maturity have already been developed in several research projects, like ATLAS, CIMsteel, COMBI or COMBINE. They resulted in standardization efforts like the Building Construction Core Model (BCCM) or STEP AP 225. Consequently, also in the A/E/C sector, product data technology (PDT) is currently on the way to commercial products, of which the Industry Foundation
Classes (IFC) are the most prominent ones. We assume them to be represented in a formal STEP/EXPRESS representation and we will enrich these models with the necessary design process related semantics.

Further discussion and open problems of the interoperability across the different layers between applications can be found in [3], but will not be elaborated further here.

Figure 1 three conceptual layer of STEP

ISO 10303 EBNF

STEP Physical File

Figure 2 Formal Representations for the different Information
2.2 Implementation method of STEP

STEP standard support many kinds of implementation method. Different kind of method map the corresponding formalization language by EXPRESS language [4]. STEP has three kinds of implementation methods:
1) File swapping: product data is described in readable and read-in text code.
2) Application programming interface: product data can be stored and fetched by designed access interface provided by different program language.
3) Database implementation: store and fetch product data with readable and read-in data or revisable data which provided unanimous expression for internal format and application interpretive modeling.

2.3 Database implementation

Comparing with neutral file realization method, database implementation is flexible and efficient in data sharing and exchanging [6]. Although STEP-based database implementation has not been set down formally, but some unofficial database implementation methods based on existed STEP standard have gotten many research results [12-15]. It is generally acknowledged that STEP-supported database management system should support EXPRESS mode and SDAI which are two basic functions of STEP [7-9]. At the same time, database management system itself required to have data definition language (DDL) and data manipulation language (DML) [5]. This required application programmer only describe the data model with EXPRESS language and operate data by SDAI, he need not care about the function of the management system [10, 11].

A database integrated method based on STEP has already been implemented as figure 3 shows. EDBMS is an independent developed database management system in the project, include object management module, store management module, transaction processing module, inquire processing module, edition management and SDAI interface module etc. EXPRESS mode converted to DDL in EDBMS is offered by an EXPRESS converter. The converter checked the content of EXPRESS SCHEMA according to EXPRESS text, which includes grammar element and grammar rule, then construct DDL description in EDBMS with conversion mechanism. At the same time, EXPRESS converter can provide the transform from EXPRESS mode to data dictionary, C, C++. Different CAD system access EDBM through its own data access interface, these data access interface is also worked out by SDAI function.

3 Product data modeling based on database

3.1 Product modeling of database implementation method

Part 11 of STEP standard offers EXPRESS language in information modeling. It has functions as follows: type, expression formula, sentence, function, process, etc. It
also adopts some technology in object-oriented such as inheritance mechanism. EXPRESS language establish the product data model through a series of explanation. These explanation include TYPE, ENTITY, SCHEMA, CONSTANT, RULE, FUNCTION and PROCEDURE, etc. [5].

SCHEMA is the outer frame which describes products data model in EXPRESS language (same as main function in C language). It described an logically independent and complete concept mode, that is the product data model in objective reality. Among all of them interface- specification provided resource sharing and quoted mechanism to different modes, which makes a certain resource in logic layer of STEP defined only once, but its usage can distribute in different explaining modes. For example, in the mode of geometry and topology, entity explaining in topological mode needs to be based on entity in the mode of geometry, if used interface_specification, there will no need to give these entity statement in topology mode repeatedly. In our system, we firstly set up information model. An integrated information based on STEP standard (SPDM) can be described as following parts.

1) GIM ( General Information Model )
2) SIM ( Structure Information Model )
3) SCM ( Shape Construction Model )
4) PFM ( Physical Feature Model )

5) MIM ( Management Information Model )

The product model above-mentioned can separate overall message of products life from concrete structure description with main characteristic pertaining method. For example, we describe tolerance and other feature in the sub surface model of SIM in order to guarantee the independent of the tolerance model. Its concrete structure shows as figure 4. Object in product information model mapped to entity of information model described by EXPRESS language, its structure layer is replaced by subclass, superclass relationship in EXPRESS. By the mapping, we can get product information model described with EXPRESS language, only give main part because of length.

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SCHEMA product
ENTITY SPDM;
  SUPERTYPE OF SPDM;
  ENTITY GIM;
    SUBTYPE OF SPDM;
      SUBTYPE OF (product_definition, context_definition,product_model, definition_model, feature_definition, support_model, resource_model, product_maintain);
    END_ENTITY;
  ENTITY SIM;
    SUBTYPE OF SPDM;
      SUBTYPE OF (spatial);
    END_ENTITY;
  ENTITY SEM;
    SUBTYPE OF SPDM;
      SUBTYPE (surface,wirefare,solid)
    END_ENTITY;
……
END_SCHEMA;

Figure 4 structure of information
Table 1. The base structure of EXPRESS entity

<table>
<thead>
<tr>
<th>field</th>
<th>ID</th>
<th>SUPERTYPE</th>
<th>ATTRIBUTE1</th>
<th>ATTRIBUTE2</th>
<th>……</th>
<th>ATTRIBUTEEn</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>STRING</td>
<td>STRING</td>
<td>TYPE1</td>
<td>TYPE2</td>
<td>……</td>
<td>TYPEEn</td>
</tr>
</tbody>
</table>

3.2 Conversion method of the product model

3.2.1 Organization and setting up of the data dictionary

Product information model is finally described with EXPRESS language and referred in the form of text to integrated system. As basic structure to define and store product data, product mode in text form can’t directly used by database to manage and store the products data, it must be changed into the form of data dictionary. Data dictionary is said to be another edition of integrated SCHEMA, it can also expressed all information in text form of SCHEMA. All entities, attributes, type, relationship information described in product data model can directly queried from data dictionary. When operated product data, the first step is to search out the original entity model in data dictionary correlated with product data operation, then create corresponding DML sentence to carry out the product data operation.

3.2.2 Implementation of EXPRESS entity norm

SCHEMA norm of EXPRESS describe an independent, integrity concept mode logically. Main content of SCHEMA norm is ENTITY norm. Display attribute is basic attribute of entity, a INSTANCE of entity is an actual object. Display attribute must get a value except it has OPTIONAL restriction attribute. ENTITY norm can clearly express the actual object having complicated characteristic and relation. It has strong description ability. Our system has realized two contents of entity norm: inheritance relation expressing and display attribute expressing.

Every ENTITY in SCHEMA expressed a kind of object with common character respectively, it can correspond to a base table in the relationship database, the structure is show as Table 1.

The table name of base table is corresponding to entity name of EXPRESS, the first field ID is the exclusive identifier to make out every instance of entity. Second section field SUPERTYPE indicates the relation with father entity, it will default this field when the entity have not father entity. ATTRIBUTE use every attribute name of this entity as name of field section, it also defines the value range of every attribute according to certain data type conversion rules.

3.2.3 Access operation of the products data in the data base

To establish product database is to implement the product data model expressed in EXPRESS language, which is based on database [6]. According to certain conversion rule and implementation method, convert the defined semantic of entity, type and relation in SCHEMA into a series of corresponding base tables of the database. In integrated environment, CAD application system stored product data in certain form to product database through CAD interface, that is to implement the automatic storage of the product data. Structure and expression way of product data are defined by SCHEMA, the concrete data structure is stored in the data dictionary.
Data dictionary is set up by user protocol which is described by entity set of EXPRESS language, so it has mapping relationship between the data dictionary and EXPRESS entity. All access operation to product data is to find out entity base table in data dictionary and the saving format in database, then establish connection route of every base table and produce corresponding SQL command sentence, finally, implement the access operation of the products data. Information model of product information is stored in STEP file format, its data storage is very large, which required working format of file has a more optimizer structure, table in database should takes up storage as little as possible, its structure shows as figure 5.

Entitylink structure

| int entityname |
| int map |
| int scopelayer |
| char *name |
| int mark |
| struct parameters *param |
| structure entitylink *extmap |
| structure entitylink *next |

parameters structure

| enum paramtype type |
| int optional |
| char string |
| structure entitylink *scope |
| structure parameters *set |
| structure parameters *next |

Figure 5 logic structure of the table

Entitylink structure stored key word of STEP (name), entity name (entitename), mapping way(map), level of SCOPE (scopelayer), external mapping (extmap), etc. corresponding entity parameter information is stored in parameters structure that param pointed to, its stored information include parameter type(type), optional or not (optional), parameter content(string), private entity(scope) and the aggregation type parameter (set). By such an entity tree, all product information in STEP file are included. Use one implementation way of entity model in STEP file to explain shortly:

#1=CPT ( 0.0 , 0.0 , 0.0 )
#2=CPT ( 0.0 , 1.0 , 0.0 )
#11=VX ( #1 )
#12=VX ( #2 )
#16=ED ( #11 , #12 )
its expression way in the table working format shows as figure 6.

4 Implementation

The STEP-based database is established on product model in life-cycle, so the product database can give whole product data that other SCHEMA-supported application system needed, the product database establishment process is the process to realize EXPRESS depicted SCHEMA application on database, convert the entity, type and relationship in SCHEMA to a series of datasheet in database according to prescribed conversion rules and realization methods, it is very important in establishing database. In integration system, product data is stored in database according to stated format, heterogeneous CAD system can directly access product database, save to and fetch from product data in database by product database interface between itself and product database, thus realized the sharing of product data. when establishing the product database for integration system, firstly, We create the data dictionary according to PRODUCT_SCHEMA, then
establish entity base table; Secondly, work out assembly and related part in Solidworks according to function requirement; Finally, extracting the entity information using the API function that the Solidworks provided, then open the related entity table in database, and decide whether saving the entity information to datasheet or not. Figure 7 shows the process from PRODUCT_SCHEMA to establishing entity base table. Figure 8 illustrates the concrete realization process from entity data inserted to database.

Figure 6 working format of the entity

Figure 7  the process from PRODUCT_SCHEMA to establish entity base table
The prototype system interface is shown in Figure 9. Using the gear as an example, the system reads gear information from database, extracting the entity information by Solidworks API function, insert corresponding entity table and decide whether insert the part information to engineering database system.

5. Concluding Remarks

In this paper, the implementation method of STEP standards is analyzed thoroughly, a relatively new approach to fulfill data exchanging by using database is put forward, the method of how to build product information model, data dictionary, entity base table information are high lightly introduced, a crucial problem to store and fetch product data in database is settled. at the same time a integrated STEP-based production information model for mechanical systems is presented, The model enables exchange of product model data in standardized format. Product modeling, information sharing and exchange of product model data in computer interpretable form contributes to product development lead-time reduction by:

1) Laying basis for systematic, integrated management of information and supporting product model applications throughout the life cycle of product development, thus improving the information process design and planning.

2) Eliminating need for human interpretation, errors and rework in data exchange.
3) Promoting data exchange to be down on the level of product data instead of document data.

Arming with supporting STEP database implementation method, we can make different kinds of CAD system to integrate more convenient. This will give a great power to CAX application and factory automation. Next job in the future, we will focus on the following issues:

1) make perfect on API exploitation platform based on STEP standard.
2) integrate the application to a more complex mechanical system so that it can support network-centric integrated distributed design which can be used in concurrent engineering.

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