STEP-BASED MODELING & SIMULATION FOR VIRTUAL PRODUCT DEVELOPMENT

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Keywords: Virtual Product Development, HLA, STEP.

Abstract: A novel STEP-based modeling and simulation method is proposed to improve the data consistency and the model reusability in Virtual Product Development (VPD). Based on the proposed method, a STEP-based product model is automatically generated from STEP files and CAD/CAE models. In the method, besides product shape data other effective data can be extracted from STEP files and CAD/CAE models for HLA-based simulation. An applicable prototype system is designed to support this method. A case study is performed to demonstrate the feasibility of the method.

1 INTRODUCTION

Virtual Product Development (VPD) is the process of designing, analyzing product and developing Virtual Prototype in digital environment. Nowadays, product simulations within a single discipline cannot satisfy requirements of VPD. High Level Architecture (HLA) is a well-known standard for distributed simulation (IEEE Computer Society, 2001). Adopting HLA, simulation systems in VPD could reuse existing simulation models, and integrate different kinds of multi-disciplinary product simulation models in one simulation task. However, HLA-based simulations cannot completely meet requirements of VPD. Simulation models in HLA-based simulation are usually independently developed without using the upstream product information. This cannot satisfy the demand of data consistency in VPD, and reduces the credibility of simulation results.

As an ISO standard (ISO 10303) which is widely used in CAD/CAE/CAM/CAPP, STEP standard (Technical Committee 184 Sub-Committee 4, 2002) supports data exchange in many product development domains. Adopting STEP standard into VPD would facilitate the reuse of CAD model information in HLA-based simulation, and enhance data consistency in the whole process of VPD.

Nowadays, the most representative projects which use STEP standard to build product models for data exchange are the Model Based Definition (MBD) project which is proposed by Boeing (Chen et al., 2009) and the Share-A-Share project designed by Eurostep (Shaw, 2009). But in these projects, STEP-based product model is mainly addressed to resolve the problem of CAD/PDM data exchange of complex product, and do not contain the simulation data that are useful for multi-disciplinary simulations. Hunten (1997) describes an approach of CAD/FEA integration with AP209. Thurman and Benda (2009) built a model-based enterprise environment with AP210. The above two researches mainly focus on information integration with single AP, and it makes these approaches hard to extend to other simulation domains. Li et al. (2008) define a STEP AP203-based logical structure of a mechatronic system using HLA, but the method of converting STEP files to domain simulation models is not described in details. Si et al. (2009) proposes an application framework of Product Collaborative Design. In this framework, STEP files are converted into domain simulation models by specific software interfaces. Using specific software interfaces limits the framework for further use.

Based on the above reviews, this paper argues that general STEP-based approach is not convenient to be used in VPD, especially for HLA-based simulations. A single application protocol can only exchange data in single domain, and is lack of the definitions of assembly constraints which are indispensable for some specific simulation domains. Furthermore, most researches mainly focus on the information of product shape. Actually, there are more useful information than product shape data

Li L., Xiao T., Fan W., Sun H. and Ma C..
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DOI: 10.5220/0003596302240227
In *Proceedings of 1st International Conference on Simulation and Modeling Methodologies, Technologies and Applications* (SIMULTECH-2011), pages 224-227
ISBN: 978-989-8425-78-2
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could be reused in STEP files for VPD.

In this paper, a novel STEP-based modeling and simulation method is proposed to improve the data consistency and the reusability of models in VPD. By this method, a STEP-based product model which is suitable for HLA-based simulation would be automatically constructed from STEP files and domain models.

2 STEP-BASED PRODUCT MODELING

In order to organize the data which is useful in VPD, this paper gives a metamodel of STEP-based product as Figure 1 shows. The metamodel specifies the model data which must be recorded in a unified form, and indicated basic elements of the model and their associations. Every product model should contain one instance of class *Product*, and an instance of class *Product* should contain one or more instances of class *Assembly*. The main information contained in class *Part* is product shape data which is specified in AP203 or AP214. An instance of class *Part* could contain one or more instances of class *Feature*. Class *ContextData* contains various application environment and context information.

Class *ProductElement* which describes the general information of product elements is associated with class *ConstrainSet* and class *DesignHistory*, which are used to specify the data not represented in STEP files but useful in HLA-based simulation. Class *DesignHistory* records the data of product design processes. Including design history in the STEP-based product model would bring product designer's intentions to the model. Class *DomainElement* is an abstract class which could be instantiated with domain-specific information. In order to store the mappings between domain elements and product part, class *MappingData* is associated with both class *Part* and class *DomainElement*. Based on class *HLAModelData*, users could define which data should be published and which data are needed in the HLA-based simulation. Several attribute data of the class *HLAModelData*, such as dataUnitType, are dependent on class *ContextData*, which improves the data consistency in HLA-based simulations.

Because of the complexity of EXPRESS language, STEP files may not contain an explicit data structure. Therefore, analyzing a STEP file to get explicit data structure is still a difficult job. Furthermore, there are many entity instances that do not contain any useful information in STEP files which are exported by upstream systems. When extracting information from STEP files, these useless instances are usually ignored manually. This paper proposes a user-friendly method which could automatically analyze STEP files with the rules defined by users and convert them into the STEP-based product model. The process of the method can be described as follows:

- Construct preliminary STEP file information set. The method makes search rules first, which contain an entity as start point and an entity as end point defined by users. Each search rule would lead to a file traversal of the STEP file in the shortest path between the points, and produce a search result whose data are stored in an appropriate sequence. The search result can be generated as Figure 2 shows. This process could be seen as a data preprocessing which would facilitate the information analysis of STEP files. Each search result is deemed as a data block, then they form a preliminary STEP file information set which contains all the information needed in VPD.

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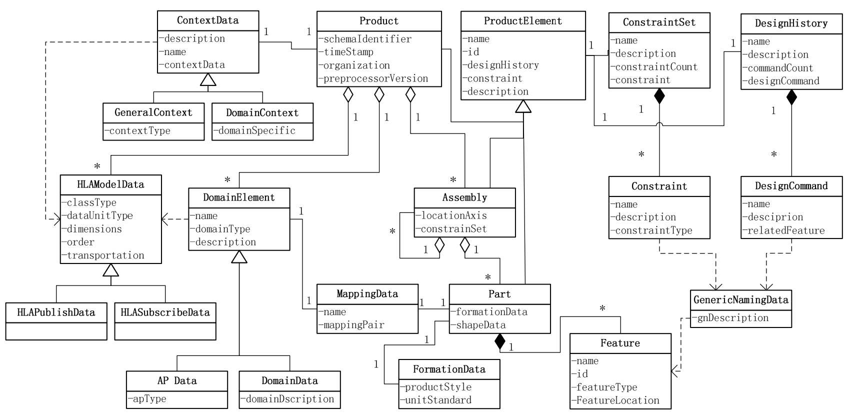

Figure 1: STEP-based product metamodel.

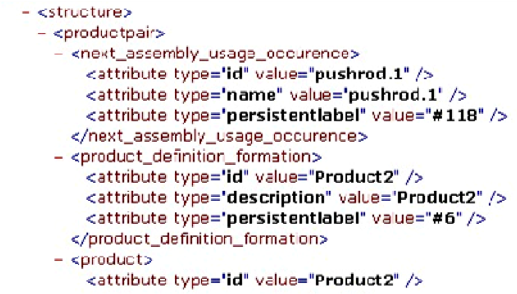

Figure 2: The search result of STEP files.

- Analyze the information set and construct the STEP-based product model. In this process, the instances of class *Product*, class *Assembly* and class *Part* in the model would be generated first, as well as their relationships. Then instances of other classes defined in the metamodel are added to the STEP-based product model. After the process, useless entity instances are removed according to the requirements of users.
- Use specific interfaces to access domain specific information from domain product models, such as product assembly constrains and design history data, and attach them to the STEP-based product model based on the architecture of the metamodel. This process would be varied in different specific domains.

For the purpose of describing and completing the processes in detail, this paper develops a grammar to describe the information set.

Table 1: Grammar of information set.

No.	Grammar rules
1	$S \rightarrow P_M$
2	$P_M \rightarrow D_{PR}R_{PS}D_C P_{style} D_{brep} D_L D_O \epsilon$
	……
76	$\epsilon \rightarrow />$
77	$\epsilon \rightarrow </\delta>$
78	$\delta \rightarrow$ (any string does not contain ternimal)

ϵ and δ are deem as terminals, and this paper denotes "<product>" as θ, "<attribute type =δ δ>" as α and so on. Handles such as $D_{PR}$and R_{PS} represent data blocks in the information set. Users could define new handles if they want to introduce new data blocks into the set. Based on rule 2, a gross deterministic finite state automata (Figure 3) could be built to describe the grammar.

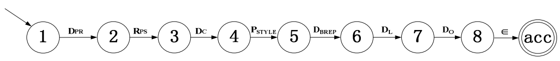

Figure 3: Gross deterministic finite state automata.

Rule 3 to 12 represent the grammar of the data block shows in Figure 2. This paper takes this data block as an example to demonstrate the process of information transformation. The augmented grammar of the data block is listed as follows:

Table 2: Augmented Grammar of the data block.

No.	Augmented Grammar rules
1	$S' \rightarrow S$
2	$S \rightarrow < structure > P_{RS}\epsilon$
3	$P_{RS} \rightarrow P_R P_{RS}$
4	$P_{RS} \rightarrow P_R$
5	$P_R \rightarrow < productpair > NP_{DF}PNP_{DF}P\epsilon$
6	$P \rightarrow \theta A_S \epsilon$
7	$P_{DF} \rightarrow \eta A_S \epsilon$
8	$N \rightarrow \gamma A_S \epsilon$
9	$A_S \rightarrow AA_S$
10	$A_S \rightarrow A$
11	$A \rightarrow < attribute\ type = \delta\, \delta\, \epsilon$

Using the rules mentioned above, the reachable item sets and the transitions between them can be found. A state machine can be represented as Figure 4. For brevity, the parsing table and attached actions for generating the STEP-based product model are not represented. Because of the serial structure of the gross finite state automata, users could easily add or remove data blocks in the information set, and modify the states in the finite state automata as well as the attach actions in order to analyze the STEP files in their own rules.

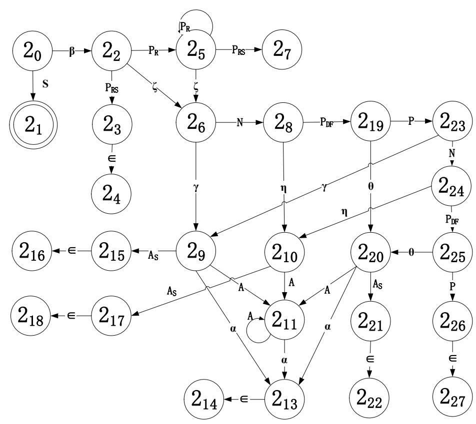

Figure 4: State machine of search result data.

3 CASE STUDY

This case is part of the research project of the National High Technology Research Development Program of China (863 Program). A prototype system is developed based on the proposed method. The prototype system could convert the information in STEP files and domain models into the STEP-

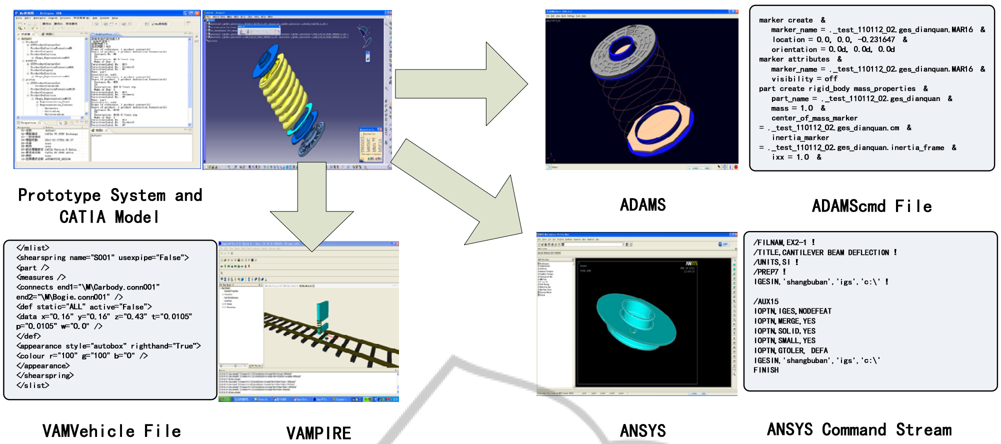

Figure 5: Part of the codes of simulation models and the prototype system.

based product models, and transform the model to several kinds of simulation domain models for HLA-based simulations. This paper mainly focus on the information extracting, so we do not describe the method of converting the STEP-based product model into several kinds of domain simulation models (such as ADAMS model, VAMPIRE model). The prototype system and part of the codes of these models are shown in Figure 5.

Compared to other approaches, the proposed method could integrate more useful information in STEP files than product shape data for simulation, and the information of domain models are also integrated. So the STEP-based product model could provide all the necessary information for design and multi-disciplinary simulations in VPD. Moreover, the method of extracting information from STEP files are more flexible and user friendly, this could facilitate simulation modeling for VPD in a more effective way.

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