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XML-based assembly visualization for a multi-CAD digital mock-up system

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Abstract

Using a virtual assembly tool, engineers are able to design accurate and interference free parts without making physical mock-ups. Instead of a single CAD source, several CAD systems are used to design a complex product in a distributed design environment. In this paper, a multi-CAD assembly method is proposed through an XML and the lightweight CAD file. XML data contains a hierarchy of the multi-CAD assembly. The lightweight CAD file produced from various CAD files through the ACIS kernel and InterOp includes not only mesh and B-Rep data, but also topological data. It is used to visualize CAD data and to verify dimensions of the parts. The developed system is executed on desktop computers. It does not require commercial CAD systems to visualize 3D assembly data. Multi-CAD models have been assembled to verify the effectiveness of the developed DMU system on the Internet.

Keywords: Digital mockup, E-assembly, Multi-CAD, Lightweight CAD file, eXtensible Markup Language (XML).

1. Introduction

Automobile and aircraft design requires a large number of engineering collaborators. Most of the design modifications related to manufacturability and assembly are required owing to mismatches and interference between neighboring parts. To reduce such mismatches and interference, real mock-ups have been used. CAD systems have been also applied to verify and check the assembly process. In order to prevent the interference and mismatches during precision design processes, DMU systems are used nowadays. Using DMU systems, designers are able to design accurate and interference-free parts without making physical mock-ups.

Rezayat [1] has applied XML to exchange CAD data. In order to exchange CAD information, he translated topological CAD information into XML data by using KBPD (Knowledge-Based Product Development). In addition, he proposed a DTD type schema called CADML (CAD Markup Language). Shyamsunder and Gadh [2] proposed a simplified assembly model, AREP (Assembly REPresentation), for collaborative design work in a distributed environment. Chen et al. [3] studied a real-time Web-based collaborative design for assembly, which is called e-Assembly. By using an ACIS kernel and a CAR (Collaborative Assembly Representation) model, they devised a real-time collaborative tool applicable to verification of assemblies. Yang et al. [4] proposed a macro data representation method of XML data for CAD model exchange. Based on XML and standard modeling command language, they constructed part databases of various CAD systems, but it was limited to part design. XML-based e-Assembly for design manufacturing has not been studied yet. In 2003, Jezernik and Hren [5] developed a low cost VR (virtual reality) system by using XML and VRML. JT of UGS [16] and HSF of Techsoft3d [15] visualize assembled parts composed of heterogeneous CAD data. However, since they are not interfaced with XML or

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STEP/PDM schema, they are not applicable to various PDM (Product Data Management) systems.

A visualization of an XML based DMU system for assembled parts composed of multi-CAD data is proposed through the visualization of the lightweight CAD file [6]. The developed system does not require expensive commercial CAD systems. In fact, the cost of ownership is cheaper than that of other systems. In addition, the system has functions of real-time interference check, dimensional inspection, and design verification of multi-CAD assembled parts on the Internet environment. The lightweight CAD data [6] are used for sharing model and assembly. XML is used for displaying and interfacing of BOMs (Bill of Materials) of assembled parts. By designing a schema based on the international standard of ISO/STEP PDM, the developed system is interfaced with most commercial PDM systems. In order to interface with other systems, modified positional information generated in the assembly process is stored as an XML format and is registered in the PDM system database.

2. Related researches

2.1 XML

XML, which was introduced at W3C (World Wide Web Consortium) in 1998, is a standard for exchanging structured documents and data in the Internet environment. XML makes users define tags arbitrarily and maintains the structure and meaning of data without any changes. It is applied to exchange data with other systems. XML displays various characters through Unicode and is independent of languages. Therefore, XML is used to exchange information between heterogeneous platforms and systems. It has interoperability as well [14].

In this paper, such advantages of XML are to be maximized to develop a digital mock-up system. Structural information schema of an XML assembly is to be designed based on the standard information, ISO 10303-28 XML rule and STEP PDM schema. It guarantees the data exchange between PDM systems.

2.2 VRML

VRML (Virtual Reality Modeling Language) appeared by releasing rule 1.0 in 1994, and has been spread through the Internet. It is now adopted as the international standard of ISO/IEC 14772-1. VRML defines the interaction between multi-medias as a programmable object by using Java script. The definition of an object is called a Node. Nodes are arranged in a hierarchical structure called scene graphs [17]. They might be distinguished from other nodes or might affect the others. However, the VRML translator in CAD system supports only text-based VRML. The text-based VRML has similar data size compared with original CAD data. It takes longer time to read the data.

2.3 X3D

After VRML was adopted as an ISO standard, XML-based X3D, developed in the Web3D consortium, was released [7]. X3D means extensible 3D and extends functions of VRML. Moreover, the name X3D represents the integration with XML. X3D was first released in 1999. Unlike VRML, X3D follows standard type of XML grammar. It has good compatibility and is extensible by the code modulization. Consequently, depending on the X3D operating environment, users are able to use necessary functions efficiently. Additional functions are defined freely. In addition, X3D supports functions of NURBS (Non-Uniform Rational B-Spline).

As X3D is designed to furnish perfect subordinate compatibility, it supports all functions of VRML, and is used to convert to X3D format by using the VRML format. Although X3D has many advantages compared with VRML, other CAD systems do not support it directly, making it difficult to use X3D for CAD data verification.

2.4 ISO/STEP PDM schema

The PDM schema [8], the standard of ISO/STEP, provides integrated modeling of product information. This is the core standard of a product information manager. As the PDM schema has general product information applicable to various AP (Application Protocol), it is extensible and flexible as a standard.

The STEP PDM schema supports a clear hierarchy representing product structure and its elements of the structure. Especially, PDM schema distinguishes not only the relationship between closed child-parent assembly, but also advanced relationship about the element definition. Fig. 1 displays several steps of assembly DMU instance. By using this, the PDM schema distinguishes every single component in the multi-assembly structure. A number of different views under each part version are defined. In addition,

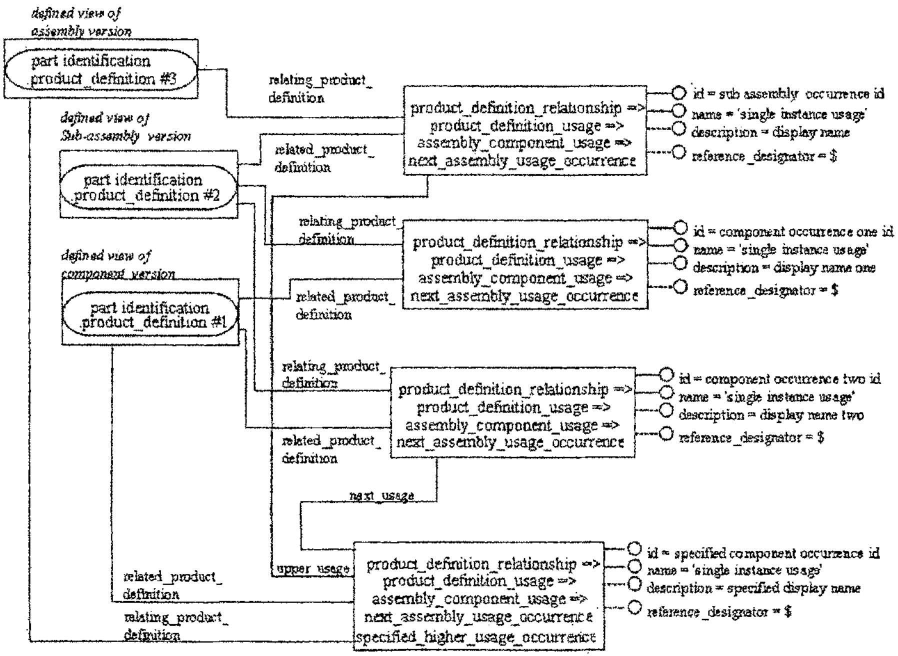


Fig. 1. Multi-level assembly DMU instance diagram in the PDM schema.

positional information, topological information, and characteristics of a component are specified and recognized. Using the 'specified_higher_usage_ occurrence' entities, higher and lower relationships of an assembly are searched.

The PDM schema is imported and used to design XML schema structure to manage and verify the assembly information designed on various CAD, PDM and DMU systems. The contents, interfaced from XML, are stored at the data storage to register in the PDM system by mapping the XML schema to a database.

3. Visualization of assembly

The visualization of assembly is designed by the PDM schema of the STEP standard. Fig. 2 shows an XML schema structure of an assembly and parts. The XML schema structure consists of subordinate assemblies called subassemblies, and its parts called components. The subassemblies are able to adopt other assemblies or parts.

The parts and subassemblies have matrix data to represent positional information. The matrix data containing the positional information are constructed with transformation matrices (V1~V9) and position vectors (T1~T3) at 'Position' of the parts or subassemblies, respectively. 'Name' in Fig. 2 means the name of the part or sub-assembly on BOM. 'Id' is a number to distinguish assemblies or parts. 'Type' means the type of link data. According to the 'Type', users are able to select an appropriate translator for visualization. 'Version' describes the version of drawings. 'Higher_info' is an entity representing higher level information, and it supports a searching function of a hierarchy in the multi-level assembly. 'Link' in an assembly supports the connection between subassemblies or parts. 'Link' in a part is connected to physical visualization data. The schema expresses up to n level assemblies and accesses CAD BOM. As the XML data is designed according to DMU of the multi-level assembly, higher and/or lower stage searches are conducted conveniently. If the assembly data structure is designed as one-directional reference type, children components of the subassemblies do not have parents' information of the children components. Thus, when a component is modified, all children components in the parent assemblies should be searched in order to understand which parents used the modified component. However, this XML schema allows easy searching when either a parent or a child is modified. Therefore, various CAD data registered in various PDM systems are easily interfaced to the developed XML schema [9].

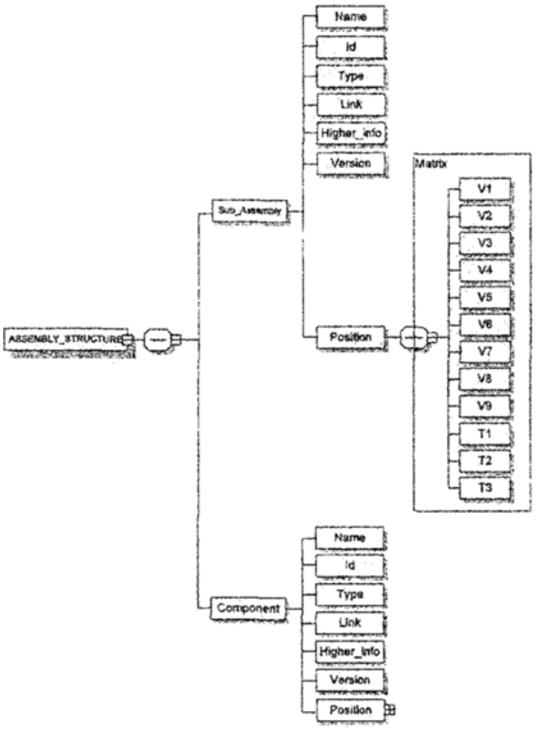


Fig. 2. XML schema structure for assembly.

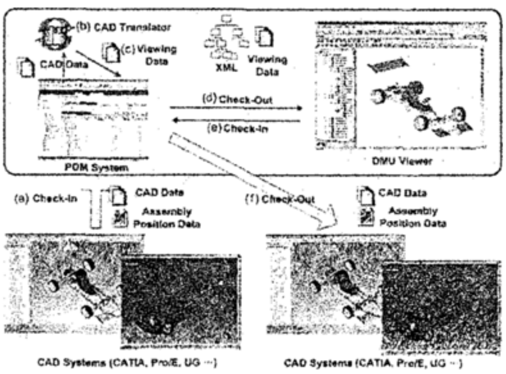


Fig. 3. Overall framework of the DMU system.

4. System architecture

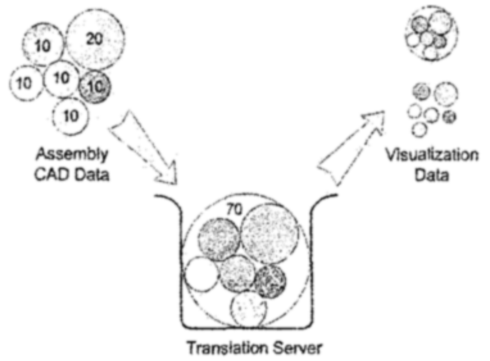
Fig. 3 shows the overall structure of the proposed system. It consists of the following modules: the CAD API (Application Programming Interface), PDM server and data base, Web server and servlet engine for Web interface, data translator for visualization, and PDM-viewer client.

The operating procedure of the system is conducted as follows. Various CAD data are registered in PDM by selecting the 'Check in' menu of the PDM system. The PDM menus are constructed by CAD API. When the CAD data are registered into the PDM, the system extracts position and assembly information of the CAD data by using the CAD API as shown in Fig. 3(a), and registers them to the PDM database. The CAD data, registered in the PDM system, are translated to visual data by the CAD Translator[10, 6] as shown in Fig. 3(b), and managed by the PDM system as shown in Fig. 3(c). When users check out an assembly needed to be verified, then the DMU Web viewer is plugged into the Web browser. The assembly XML and the lightweight CAD file as visual data of components are visualized on the Web viewer as shown in Fig. 3(d). After verification by the assembly DMU, the system checks in the assembly on the viewer, and then delivers the changed assembly position by XML and shows it (Fig. 3(e)) [9]. The verified file, checked by DMU web viewer, is able to be verified again on CAD systems. To be verified on the CAD system, the file should be searched through the PDM system, and then 'Check-out' to the CAD system (Fig. 3(f)). By following these procedures, users are able to check whether the CAD data have interferences. If there are interferences, clients can modify them and register modified data through 'Check-in' procedure of the PDM system.

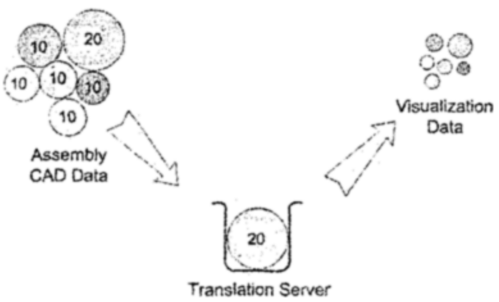
5. Generation of visual data

Most PDM systems convert CAD data into visual data for efficiency and security. In this paper, visual data are generated separately as the component file and the assembly information. CAD data corresponding to the part generate visual data after conversion, but the other CAD data corresponding to the assembly store both connecting and position information as matrices including the visual data. These assembly data corresponding to sub-parts of the PDM system data are obtained without conversion. Using the information, clients are able to search the data on the PDM. An XML-writer generates an XML files to be used for visualization. The XML-writer was developed by using Xerces XML Parser [18].

In general, the generation process of visual data converts all CAD data (size 70) of an assembly at once in the translation server as shown in Fig. 4(a). In addition to the conversion of the part data, the conversion (size 70) of the assembly itself is required as well. Since the two conversions are required at once, a high performance translation server is mandatory. However, using the proposed method of this paper, only the conversion of visual data of parts is required.



(a) Conventional translation process



(b) Proposed translation process

Fig. 4. Comparisons of translation processes.

Minimum requirement of the translation server is limited to the size 20 of the maximum part as shown in Fig. 4(b). If an assembly is composed of duplicated parts, the visual data might be reduced remarkably. If there are frequent design modifications, the translation server should have big capacity for data storage. However, as only the visual data of the modified parts are required in this paper, clients are able to save memories and reduce the server size remarkably.

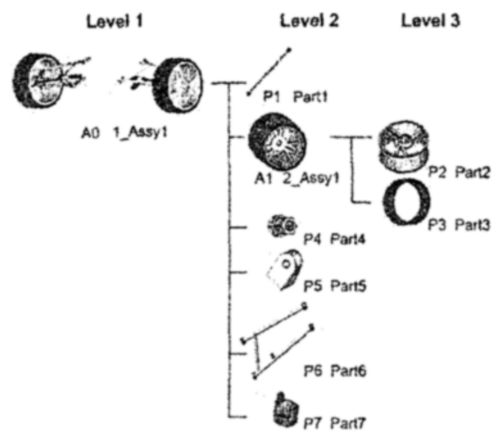
Table 1 shows the translated data size of the original CAD data shown in Fig. 5. It consists of A0~P7 parts. The third column shows the data size of the previous visual data [11]. The fourth column is the data size of the proposed visual data generated from the developed system.

6. Assembly data management in the PDM

The management method of assembly data is as follows. First, extract part feature and positional information from the assembly. Define the extracted positional information according to the relative position in the assembly structure. 'Id' in Fig. 5 means the identity information of each part and assembly. The assembly table denotes interrelation between the assembly and subordinated parts. The system stores the parent 'Id' value to the 'Higher info' element, and then stores the child 'Id' value to 'Link'. A part's relative positional data corresponding to the higher

Table 1. Comparisons of visual data size.

DataName	Original CAD file size (MB)	Previous [11] visual data size (MB)	Proposed visual data size (MB)
A0	70	7	-
A1	20	2	-
P1	10	1	1
P2	10	1	1
P3	10	1	1
P4	10	1	1
P5	10	1	1
P6	10	1	1
P7	10	1	1
Total	160	16	7



(a) Structure

Id	Name	Higher_info	Link	Position
A0	1_Assy1	NULL	A1	NULL
P1	Part1	A0	V1	$M_{2,1}$
A1	2_Assy1	A0	P2	$M_{2,2}$
A1	2_Assy1	A0	P3	$M_{2,3}$
P2	Part2	A1	V2	$M_{3,1}$
P3	Part3	A1	V3	$M_{3,2}$
...	...	...	...	...

(b) Database table

Fig. 5. PDM database structure for an assembly model.

assembly is stored in 'Position'.

Fig. 5(a) shows an assembly with three-levels. The assembly and subassembly in Fig. 2, which is the assembly XML structure, should be expressed as a linked structure. Additionally, the linked structure between the assembly and subassembly in Fig. 5 should be identical in the database. To keep it and to save the assembly data in the database, it is designed as shown in Fig. 5(b). The design contents are as follows. Identity numbers of each assembly and part are A0, A1, P1, P2 and P3, etc. Connectivity of A1 is defined at the third and fourth rows of Fig. 5(b). A 'NULL' value is stored at both 'Higher info' and 'Position' columns because the main assembly A0 does not have any parent parts. The 'NULL' value means that there is no argument. Since the parent of A1 is A0, A0 is stored in 'Higher info'. On the other hand, A1's children are P2 and P3, so both P2 and P3 are stored at 'link'. Parts P1, P2, and P3 save their parent information at 'Higher info'. The parents mean assemblies.

Visualization data V1, V2, and V3 are stored at 'Link'. Positional information is found by multiplying the position matrices on the path. For example, position P2 is calculated by multiplying $M_{3,1}$ of P2, $M_{2,2}$ of A1, and A0. However, A0 does not have a matrix, and the position matrix of part P2, M_{part2} is calculated by multiplying $M_{3,1}$ and $M_{2,2}$ in the order from the lower level to the higher level as given by Eq. (1).

$$M_{part2} = M_{3,1} \times M_{2,2} \quad (1)$$

7. Case study

7.1 Application of the XML schema

To implement the developed assembly verification system using XML, the previously developed lightweight CAD translator [6, 12] and the XML file composer developed in this paper are applied to the system. Oracle is used as a database of the PDM system. Fig. 6 shows an example of an XML file and the lightweight CAD data generated when the visualization data is required in the PDM system. Fig. 6(a) saves the relative position data of each part to 'Position'. Fig. 6(b) saves link information of the real visualization data to 'FilePath'. The visualization data link of (b) is connected to Fig. 6(c) to visualize data. When these parts are connected to the CAD system, they are replaced with CAD data. Finally, DMU verification is conducted on the CAD system.

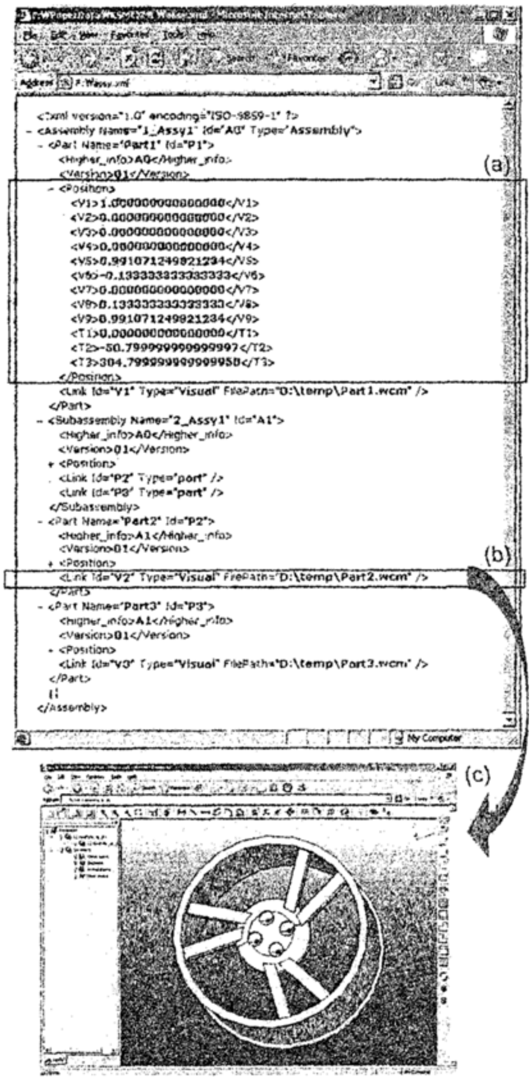


Fig. 6. CAD assembly using an XML file.

7.2 Application of multi-level assembly

A bogie assembly shown in Fig. 7(b) is used as a case study. It is a three-level assembly as shown in Fig. 7(a). CAD data designed by CAD systems are registered in the PDM system through the 'Check in' process. Using this function, all part files and conversion matrices at each level of the assembly are registered on the PDM system at once. The registered assembly file is verified step by step through the various searching functions of the PDM system. The assembly at each level is able to be visualized and DMUed by the viewer [13].

The method of expressing the multi-level assembly of the proposed viewer is by expressing the parent

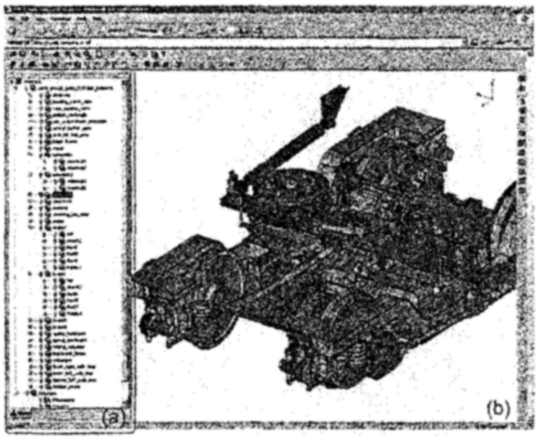


Fig. 7. Bogie assembly for multi-level DMU.

and subassembly by using a "Group" entity. The "Link" of the parent assembly expresses the subassembly, which is expressed by the "Group". The "Link" of the subassembly is linked to "Solid". Here, the three-level assembly shown in Fig. 7 is visualized with the Group-Group-Solid structure. In addition, this system represents the BOM structure of an assembly as shown in Fig. 7(a). It confirms that the case study is a three-level assembly. It is concluded that the developed system is able to be applicable to visualization and DMU at any level of assembly.

8. Conclusions

By designing an XML-based Digital Mock-up system for multi-CAD assembly, following conclusions have been obtained:

(1) Using XML technique, the data structure of the multi-CAD assembly is constructed. The XML-based DMU system is devised and verified.

(2) As the XML-based assembly system is designed according to the international standard, STEP PDM schema, the developed system is interfaced with various PDM systems.

(3) As the feature information is constructed through the lightweight CAD data and the assembly data are designed by XML, multi-level assembly and visualization of the feature data are performed efficiently.

(4) Visualization data of an assembly are divided into parts and sub-assemblies. As the parts include feature data and the sub-assemblies include only the positional data of each part, all visualization data are generated and managed very efficiently.

(5) As the system is applicable to visualization of the assembly data through the conversion of parts of the visual data, the advantage of the developed system is maximized when it is used to design an assembly requiring frequent design modification.

(6) Effectiveness of the multi-level assembly of heterogeneous CAD files linked with the PDM and DMU viewer systems is confirmed through case studies.

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