CAD Data Exchange Using the Macro-Parametrics Approach: An Error Report

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Abstract

CAD data exchange is vital to industrial engineering innovation. Because companies use different CAD systems, and there are collaborations between these companies, CAD data exchange is essential to complete the whole design process. Because the current ISO10303 (STEP) does not provide a mechanism to exchange parametric information among CAD systems, we are trying to solve this problem based on the Macro-Parametrics Approach (MPA). The entire implementation is based on TransCAD, which bridges different CAD systems. Translators of famous CAD systems are also implemented based on TransCAD. In this paper, test rallies among those translators and errors which are found during the test rallies with a simple CAD model are summarized and analyzed.

Keywords: Data Exchange, CAD, Macro-Parametrics Approach, Neutral Format

1. Motivation

Exchange of product models among different CAD systems is important to industry and engineering applications. Feature based parametric technology of commercial CAD systems can quickly generate product models by changing the design parameters. For the data exchange of CAD models, there are widely known standards such as ISO 10303 (STEP)[17], IGES which define schema of product data models. But they do not provide a mechanism to exchange the parametric information.

The Erep project of Hoffmann et al[1] defined the Erep file format as a neutral format that specifies modeling features, constraints, and assembly models. The contribution of the Erep project is that it laid the groundwork for the exchange of parametric information. Rappoport proposed the Universal Product Representation (UPR)[2] to exchange the parametric information. UPR is to support the union of data types supported by commercial CAD systems. Rappoport used a geometric model when the data types cannot be exchanged by using only the parametric information. UPR is now being used at Proficiency, a company that provides interoperability software for CAD/CAM/CAE systems.

The ISO 10303 STEP application protocol AP203 defines the B-rep geometry of a model, but it does not handle features, constraints, or construction history, which are important in a commercial CAD system. However, there are new Parts of ISO 10303, such as Part 55, Part 108, Part 111 [3~5] to cover this kind of information. Pratt et al[6,7] proposed a solution which applies these new Parts of ISO 10303 to the parametric data exchange of CAD models. Kim et al [8] suggested a method for the CAD data exchange while preserving the design intent, based on the use of the newly published Parts of ISO 10303, and a prototype translator has been implemented and tested.

In this paper, we have implemented translators for several CAD systems based on the Macro-Parametrics Approach(MPA), and introduce several problems which are found while implementing the translators.

2. The Macro-Parametrics Approach

The Macro-Parametrics Approach[9,10,13,14] is a history-based parametric approach. In this approach, the macro information, which is the recording of the modeling commands sequence or the modeling history, is exchanged**.** The idea of the Macro-Parametrics Approach comes from three following background hints; the SQL log file for the recovery from a database crash[15], the Scheme file of the Tribon Hull system of shipbuilding CAD[16], the general case parametrics of Dick Whittenum[17].

2.1 A set of neutral modeling commands

To exchange CAD models using the Macro-Parametrics Approach, a set of neutral modeling commands has been developed [11]. Modeling commands of well-known commercial CAD systems are analyzed. The analyzed CAD systems are shown in Figure 1. These modeling commands are grouped into several types, and a set of neutral modeling commands has been generated. The mapping relationships between the neutral modeling commands and the corresponding commands of commercial CAD systems are defined and shown in Figure 2.

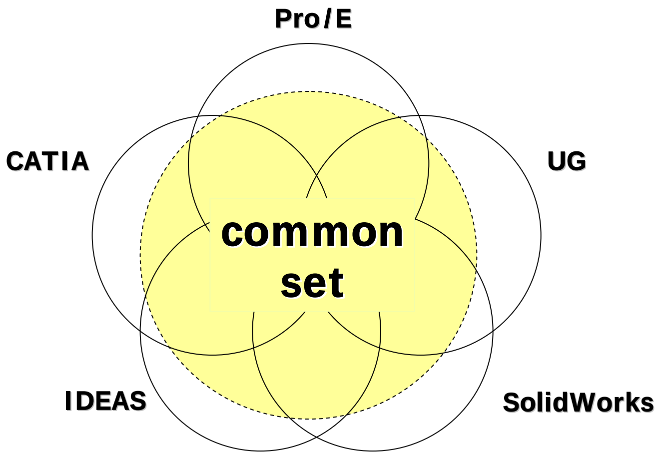


Fig. 1 Coverage of the neutral modeling commands set[11]

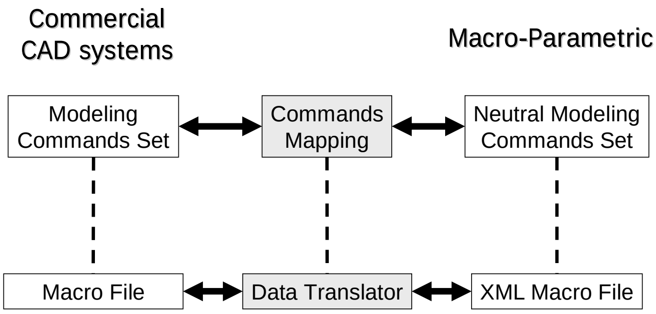


Fig. 2 Mapping relationship of the Macro-Parametrics Approach[11]

2.2 System architecture of implementation

The implementation is based on the method proposed in Kim et al's work [12]. The entire system is based on one integration platform called TransCAD, which plays the common interface between various translators and the XML file of the neutral macro. Figure 3 shows the relationship between the translators, the XML macro file, and the TransCAD. The TransCAD provides common API (Application Program Interface) functions for the various translators to handle the neutral MXL macro file and the internal geometry. ACIS is used as the geometric kernel of the TransCAD.

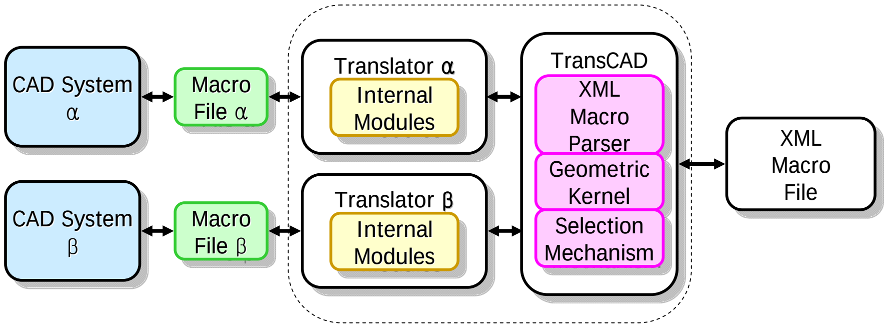


Fig. 3 System architecture of implementation[12]

3. Error analysis of model exchange experiments

3.1 Test rally

The test involves translation processes among several commercial CAD systems. The L-Block model (Fig. 4) is chosen as the test model. The basic translation procedure is that, it is modeled inside one CAD system, then using the pre-processor of the corresponding translator, the L-Block is converted into the XML file which is based on the neutral format of the MPA. Then, the test CAD model L-Block is converted again into another CAD system through the post-processor of another translator. Figure 4 shows the data exchange scope among several commercial CAD systems, and Table 1 shows the result of this test rally.

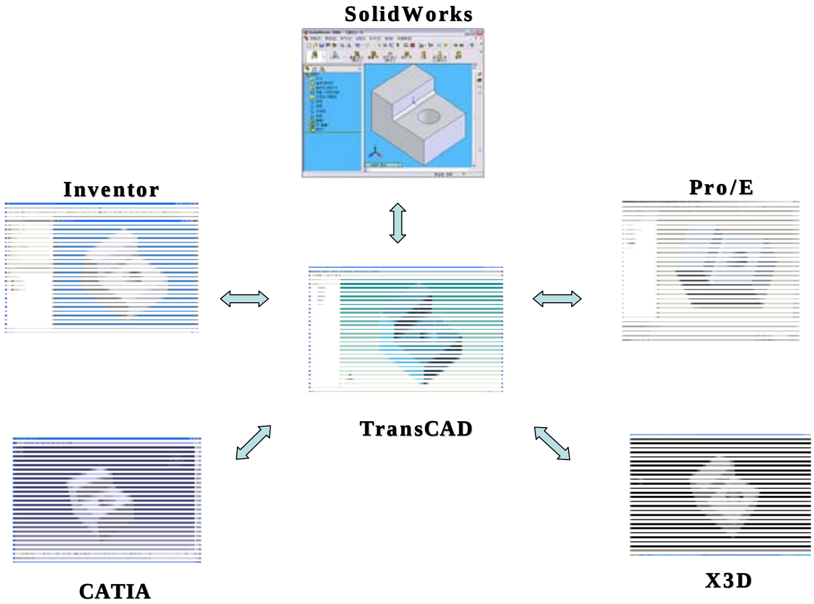


Fig. 4 Translation among several CAD systems based on TransCAD

	CATIA		Pro/E		UG		SW		FEM		X3D		Inv	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post		Post		Post	Pre	Post
CATIA	0	0						0				0		△
Pro/E		×	0					△				0		△
UG		×						0						
SW Macro		0					0	0				0		0
FEM														
X3D														
Inventor		0						0				0	0	0

O: Successful
△: Successful after manual editing or partial implementation
×: not work

Table 1 Result of Test Rally (based on L-Block[K1] model)

Note: SW (SolidWorks), Inv (Inventor)

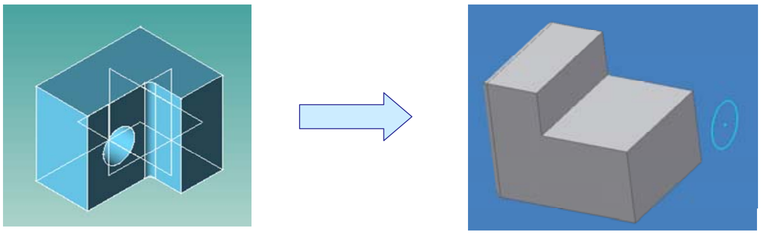
3.2 Error analysis

Interoperability is defined as ‘the ability of models of one specific CAD system to accurately represent objects in other heterogeneous CAD systems’. Representational errors may develop in either topology or geometry. Topology describes the connectivity between spatial entities. Shells, faces, edges and vertices are topological entities. Geometry refers to the position of spatial entities. Surfaces, curves and points are geometric entities. While topology errors are usually catastrophic, geometry errors are subtle and may depend on context[18].

Interoperability errors arise from many sources. Topology errors often result from internal differences between applications. Examples include utilization of different mathematical representation schemes, propagation of numerical errors along the process chain, and using different algorithms for model evaluation[19]. Whereas, geometry errors are often attributable to the user of the native modeler, commonly due to inappropriate design procedure or impractical design intent[18].

Most of translation procedure works well at the test rally. However, there are several problems while translating the test CAD model.

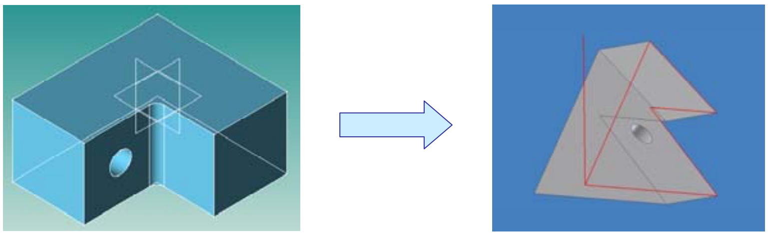
From CATIA to Inventor translation test, the L-Block model of CATIA is converted into TransCAD through the pre-processor of CATIA translator, and the L-Block is again translated into Inventor. Figure 5 shows the translation result from the XML macro file of TransCAD to the Inventor part file. In the left-hand side of the figure, the L-Block model has been converted from the CAITA pre-processor to the XML macro file, and then displayed in the TransCAD. In the right-hand side, the model is regenerated using the Inventor post-processor, and displayed in the Inventor system. There are no fillet or hole features in the final part file of Inventor. The reason is that the CATIA system uses different terminology of “pad” or “pocket” instead of the neutral terminology of “extrude” or “hole”. Therefore, it brings confusion while reading the XML macro file. Therefore, the possible solution is to match the corresponding terminology that is used in the translation process. For example, we can make a dictionary table which provides the mapping information between similar but different terminologies. Although the words use different syntax but have the same meaning. They point to the same thing in the whole translation process, such as “pad” and “extrude”. If we define “pad” and “extrude” as “extrusion_operation”, which has the same meaning in the pre-defined dictionary table, then the whole system use one unified terminology for several similar words, hence, the ambiguity of terminology problem could be removed.



TransCAD XML Macro File   Inventor Part File

Fig. 5 Translation errors between the macro XML file of TransCAD from CATIA to Inventor

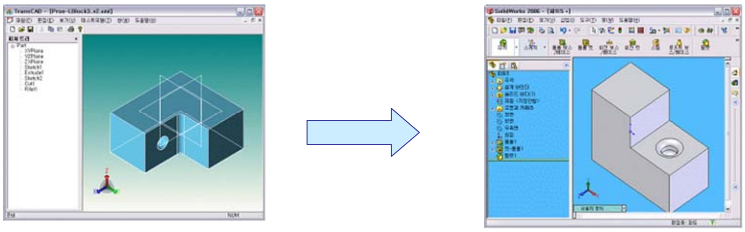
From Pro/E to Inventor translation, an incorrect result is found as in Figure 6. The L-Block model is converted from the Pro/E pre-processor, and displayed in the TransCAD. In the right-hand side, the model is regenerated using the Inventor post-processor, and displayed in the Inventor system. The reason for this error is that the modeling sequence is not the same and the corresponding constraint is not given either. It is a kind of topology error, more specifically, it is caused by inconsistency of model entity according to the error classification of Gu's work[18]. To reduce this kind of errors, we can give a modeling guideline to practicing modelers. Because there are a variety of ways to create one model, it is not easy for the translator of one CAD system to handle every possible case. Another solution is that while developing the translator, we can add constraints into the importing module of the translator. The importing module reads in the XML data while checking whether the imported data is valid or not.



TransCAD XML Macro File **Inventor Part File**

Fig. 6 Translation errors between the macro XML file of TransCAD from Pro/E to Inventor

Another incorrect result occurs while translating between Pro/E and SolidWorks, which is shown in Figure 7. The L-Block model is converted from the Pro/E pre-processor, and displayed in the TransCAD as the left-hand side. In the right-hand side, the model is regenerated using the SolidWorks post-processor, then displayed in the SolidWorks system. In the right-hand side of the figure, we can see that the fillet is created in the wrong position. The error is caused by the different selection mechanism of the SolidWorks system. The error is related with the persistent naming problem[20]. Because the SolidWorks system provides a geometry-based method of entity selections, hence if the proper entity is not correctly selected, then the fillet feature is created based on the previous feature operation – cut extrusion. So the fillet feature is generated around the circle, which leads to the incorrect result. It is categorized as a loss of semantic information case or, more strictly, a case of inability to represent model contents in the target system[19]. It could be tackled by a unique naming convention of geometry entity of the model and its mapping method between different systems.



TransCAD XML Macro File **Solidworks Part File**

Fig. 7 Translation errors between the macro XML file of TransCAD from Pro/E to SolidWorks

In addition to above three cases, from the Table 1 we can see that between CATIA and UG, and between CATIA and Pro/E, there are other errors. The system could not create the correct models. The possible reasons are associated with the modeling sequence.

In summary, there are several reasons to cause errors while exchanging a CAD model from one system to another system. It can be caused by terminology inconsistency used in distinct CAD systems, or caused by different modeling method, or the reason could be the entity selection mechanisms which are not consistent among different CAD systems.

4. Conclusion

In this paper, we have reported errors found during the data exchange test rally among different CAD systems using the TransCAD translators. TransCAD translators are implemented based on the Macro-Parametrics Approach. The possible reasons for the observed errors are analyzed and summarized.

Firstly, terminologies that are used in different CAD systems to represent the same feature can be different. While generating the neutral XML macro file, the translation result can be different because of the terminology difference. Therefore we should find the terminology correspondence in a mapping table before generating the neutral XML macro file.

Secondly, the coordinate system can cause problems. Because a CAD system such as SolidWorks mostly uses the global coordinate system as the basis coordinate system, and sometimes, when creating a sketch, it uses a local coordinate system, but it is not easy to reflect the mechanism in the translator. In addition, if another CAD system uses a local coordinate system as the basis, then during the data exchange procedure, the corresponding information can be misleading, which can cause errors that have not been expected by the translator.

Thirdly, one of the well known problems of data exchange – is the persistent naming problem[20]. It is vital to the data translation process, but is quite difficult to resolve. While creating an internal geometric model in a CAD system, there are several ways to generate the CAD model entities. However, during the data exchange process, the distinct modeling entity can be differently represented and it usually causes unexpected errors.

In addition, in terms of system accuracy, different systems or applications have different definitions and requirements for accuracy. For example, some CAD systems assume relative accuracy as the default, while others assume absolute accuracy. A suitable value of accuracy in one system may be not sufficient in another system due to different representations or algorithms. Thus, consistent settings of accuracy between different systems are critical to the proper exchange of CAD data. However, different systems define and utilize accuracy differently, determining appropriate settings during data exchange can be challenging[18].

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