Transdisciplinary Lifecycle Analysis of Systems
R. Curran et al. (Eds.)

doi:10.3233/978-1-61499-544-9-615

Advances in Parameterized CAD Feature Translation

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Abstract. This paper describes the challenges, solution approaches and recent achievements to provide the translation of parameterized feature-based models between different CAD systems, in terms of the design history of the models concerned. Such procedural models have the advantage of being easy to edit following an exchange, by contrast with the boundary representation (B-Rep) models that can be exchanged using current STEP methodology or similar proprietary solutions, which prove to be difficult or impossible to edit and reuse in the receiving system. Such enhanced CAD translation is necessary in many process chains e.g. engineering collaboration. The use of the described solution has already been demonstrated in the translation of realistic procedural shape models of mechanical parts, and the paper includes a brief description of five industrial application cases conducted in several industries.

Keywords. Data Exchange, CAD, Form Feature, Parametrics, Data Exchange Service Center

Introduction

Studies show that approximately 80% of design solutions in the automotive industry are variant designs, respectively adaptations of existing solutions [1]. The full potential for cost and development reduction inherent in variant designs cannot be implemented yet due to restrictions relating to the data exchange. The exchange of fully modifiable designs including parametric and feature information across different CAx systems was not possible for long time neither in a standardized nor in a proprietary way. It should not be left unmentioned that some CAD vendors have first solutions for the import of CAD models stemming from a different system while maintaining the feature information. But these approaches are unidirectional and neither full functional nor yet standardized.

In the context of these changing development processes, designers and developers of various cooperating enterprises no longer merely exchange geometrical data among each other, but the exchange increasingly extends to developing knowledge and information of the engineering design process. This includes technical specifications, design guidelines plus geometrical and developmental dependencies between structural components [2].

Most decisive development in order to meet these work processes is the integrated product model that enables a common understanding of product information

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throughout the entire product life cycle. Its realization can be found in the ISO 10303 ‘Product Data Representation and Exchange‘, but is better known by the informal work name STEP (‘Standard for the Exchange of Product Model Data‘) [3]. With the expanding utilization of CAx systems, the main difficulty lies in the increased use of various heterogeneous CAD systems activities, particularly in the lack of interoperability among these systems. The requirements for the exchange of product defining data are resulting from the objective to link all data processing systems into a computer integrated production process and to make the product defining data available for integrated information processing. STEP provides the possibilities to transfer the shape of a product model in terms of geometry and topology of a product successfully [4]. However, with modern CAD systems it is possible to build models that contain additional information such as parameterization or geometric and non-geometric conditions [5]. Substantial efforts have been spent to extend the initial STEP AP 214 definition for exchange of parameterized feature information [6]. Apart of many prototypes [7] [8] [9], no major CAD vendor has implemented this specification in a productive release yet.

1. Parametric Product Data Description

A prerequisite for a product model is to depict data from all phases of the product life cycle as well as various physical product characteristics and to take into account the views of the different fields of application, whereas in this case it is a so-called integrated product model [10].

Parametric modeling is a method that is based on the bidirectional associativity of geometry and measure. In the bidirectional associativity a mutual dependency is achieved in that the geometry can be modified by changes in the parameters. From an initially large number of methods for product description later the two methods ‘Constructive Solids Geometry‘ (CSG) and ‘Boundary Representation‘ (B-Rep) asserted [10].

In principle, the method CSG is based on the combination of volumes or volume primitives such as cuboid, cylinder or sphere by Boolean operations (logical operations e.g. ‘*union*‘, ‘*intersection*‘ as well as ‘*difference*‘) that are saved within the origination process (binary field, construction history). Because of the linear representation of the formation history this is called generative modeling, procedural or implicit approach or due to the legislative history of the model ‘History Based Modeling‘ [10].

Parallel to the CSG method, the method of ‘Boundary Representation‘ (B-Rep) came to existence, also written for solid modeling, it describes volume by the geometric and topological elements limiting them. Therefore this is also called geometric, topological model or method, respectively an explicit approach. While at CSG method variable dimensioned volume primitives with a fixed topology were introduced, there were, for example, so-called ‘Sweeping‘ procedures developed for the B-Rep method. This allowed generating volumes via custom therefore topology variable contours, so-called Sketches, by rotation, translation and trajection [10].

The advantages of both modeling methods were combined in a so-called hybrid or dual modeler, which operates on the ‘Dual-Representation‘ method. Even modern systems for feature-based parametric modeling resemble the same basic design of the first hybrid systems (Figure 1).

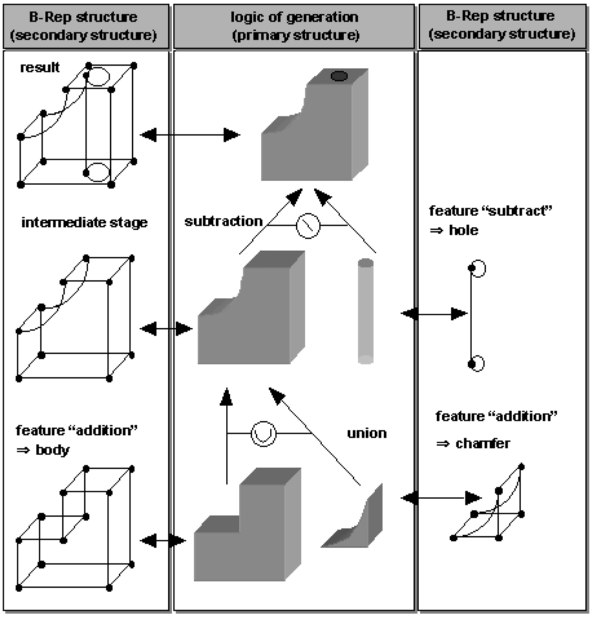

Figure1. Example for the structure of a hybrid model.

2. Extension of STEP

After STEP has been established in the CAD / CAM environment for several years as a stable, neutral interface for data exchange including information of the entire life cycle of a product model, STEP's biggest limitation is the after a data exchange existing static explicit representation of the model. In the receiving CAD system there is largely only information of the model that is represented with the description of B-Rep and contains no more engineering design intentions. All information, such as parameterization ('Design Freedom'), geometric constraints ('Design Restraint') or information on feature-based modeling ('High-level' engineering design operations) that were included in the original system is lost during data exchange. As a result, imported STEP models are called 'Dumb Models', which are editable only in limited scope within the receiving CAD systems.

By an extension of STEP or an alternative interface it is to be achieved that there are dynamic models available in the receiving system, so that the shape and properties can be modified in the respective CAD system with the information being exchanged during data transfer, such as parameters, geometrical constraints and features. This would enhance an imported model from a 'Dumb Model' to a so-called 'Intelligent Model' or 'Smart Model'. There are two different approaches to obtain the model descriptions already mentioned providing additional information, instead of the data currently held by static models of a data transfer ('Dumb Models').

The first approach links parameters with the dimensions of elements that are explicitly described in a model and defines constraints as relations between groups of entities [11]. Examples of geometric constraints would be parallelism, orthogonality or tangentiality. The representation happens with geometric and topological entities, e.g.

the ones defined in ISO 10303-42 [12]. One problem-solving approach to the extension of the explicit models would be the part ISO 10303-108.

The second approach is based on the engineering design history [13]. This procedural or history-based approach stores the procedure or the sequence of operations by which the model was generated. Constraints are represented in the engineering design operations by an implicit form of description [10].

2.1. Extensions of STEP on the example of the sweep models

Potentials for implementing will be shown here by means of a data model out of sweep models because they are very suitable as test models due to their partly explicit and implicit representation. Sweep models are created on the basis of a two-dimensional contour, which are described explicitly in the CAD systems. This contour is used to model a solid body, which is only described implicitly using one of the possible operations for creating sweep models such as translation, rotation or trajection.

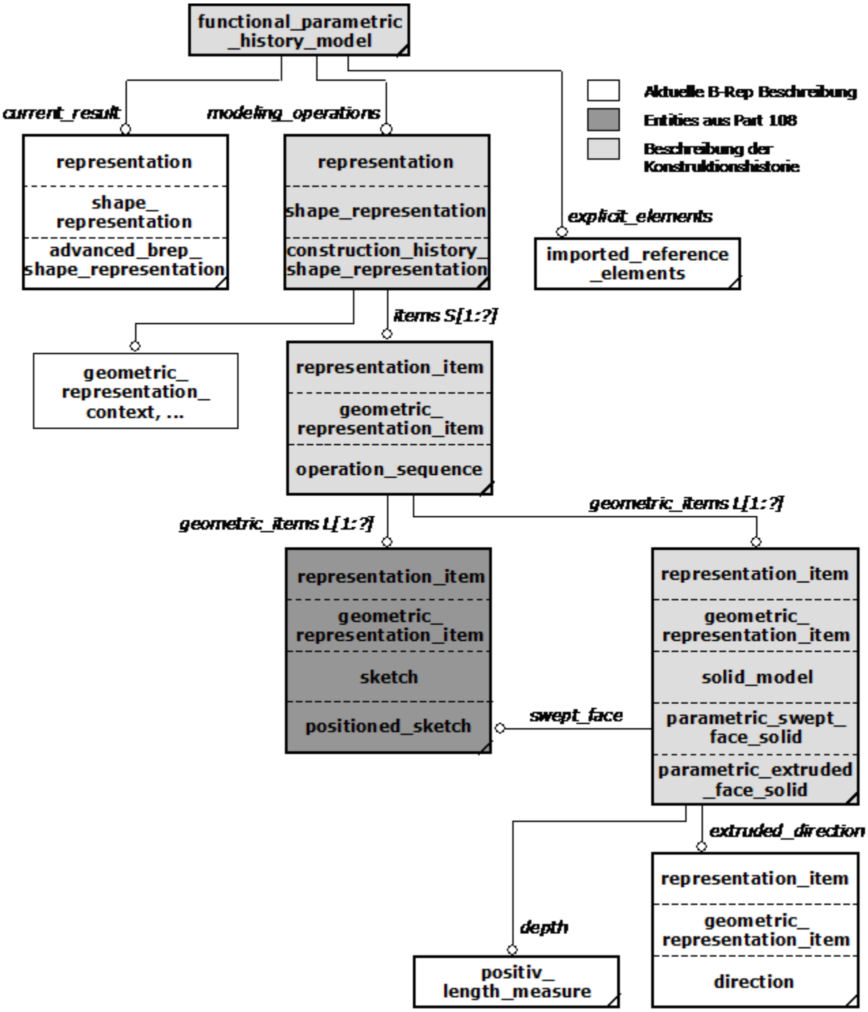

Figure 2. Description of the engineering design history in the STEP file.

A parametric representation of the sketch could be done by an implementation of the part 108, which offers an extension of the description of STEP file by parameters and geometric constraints. STEP processors do not interpret a sweep model as such, but only represent the geometric shape. The schema '*sketch_construct_schema*' now offers a range of entities with which a sketch can be described [13]. For geometrical description of the sketches, this schema refers to elements of ISO 10303-42. There are the topological and geometric entities defined, with which the contour data is represented as a line, which is necessary to create a sweep model [12].

The scheme for sketch specification also refers to the scheme defined in Part 108 '*explizit_geometric_constraint_schema*', hence geometric constraints can be inserted into the sketch. Thus, the sketch would be parameterized with the additional information after a data exchange and it would be possible to modify the diagram in the receiving CAD system. However, there is still no link between the sketch and the solid model. Although the model was constructed by performing a corresponding operation on the contour, this dependency is lost during data exchange.

One way to achieve this form of representation would be the definition of a schema to describe the engineering design history. By a representation of the sequence of operations used in the construction of the model, the design intent may be transmitted within a data exchange. An entity '*parametric_history_shape_model*' could be defined as the supreme element for this purpose. This entity refers to the conventional description by the method B-Rep on the one hand and on a new parallel description by the CSG method on the other. The part of the model description that characterizes the model with its construction history, is represented by the supreme entity '*construction_history_shape_representation*'. This refers by an attribute '*items*' to the entity '*operation_sequence*', which could represent the order of operations. This entity refers to all the substructures of the model created by various operations. The operations in turn refer to the respective elements on which they are to be executed. Thus, for example, an operation for phase creating refers to a defined edge.

Figure 2 shows the architecture of the model description according to the method 'Boundary Representation' and provides in parallel the instantiated engineering design history. This model description was supplemented by the elements of the Part 108.

3. Proprietary Solution Suite from Elysium

Elysium has developed a rich geometry-handling and data translation technology for support of rapid development of high quality products. It has closed the gap that it takes too long to import the data, the performance degrades when moving or scaling up/down the model, especially when handling large data, for example, planning the layout of engine compartments. Elysium's enveloping function unblocks these bottlenecks by reducing the data size (solid enveloping and deleting interior parts) and realizes the smooth, stress-free investigation of assembly performance.

At die design and die manufacturing, it is very important to translate high-fidelity B-Rep from product design data. Elysium's geometry healing; detecting and repairing PDQ (Product Data Quality) errors, well supports this requirement. It is required to translate 3D data accurately including non-geometry information such as manufacturing properties also when moving to the designing of equipment and jigs.

3D CAD data of products and dies are also utilized to quickly study the optimum manufacturing process and procedure in the viewer. Elysium's technology facilitates translating 3D data for viewers accurately including geometry and property information. The following four application cases shall demonstrate these capabilities.

3.1. Toyota Motor Corporation

Toyota Motor Corporation (TMC) adopts two-CAD strategy with CATIA V5 from Dassault Systèmes and Creo Parametric (formerly Pro/ENGINEER) from PTC as the main CAD systems for product development. So it is essential that two CAD systems are well linked and cooperated to each other at every process in product development to successfully and efficiently maximize the capability of each application. To promote this project, Elysium is certified as the solution provider for the capability to translate accurately, especially the complex geometry or assembly structure which is specific to automobiles, while maintaining the interoperability between two CAD systems.

TMC also utilizes other appropriate tools for specific engineering fields such as Product Development, Analysis, Production Engineering, Manufacturing etc. This technology is fully utilized to accelerate the data circulation among multiCAD and multiple systems, and improve the PDQ (Product Data Quality) in each engineering field. With Elysium's geometry handling and data translation technologies, they streamline the data circulation and realize more advanced 3D data utilization at TMC, and also smooth version-ups of each system as new versions released.

TMC utilizes Elysium's various technologies; geometry optimization, data translation of property information and new technology to handle polygon and point cloud data as well as the CAD data translation. For the quality control at the actual production line, TMC has developed a quality determination system of the products in which Elysium's technology is widely utilized. This is the system to scan the actual automobile parts from the normal production using 3D scanners, and then examine the quality using the obtained point cloud data.

Furthermore, at the plant, they are also promoting a large-scale project to study the possibility of utilizing point cloud data obtained by 3D-scanning the production line with the long-range scanners. Elysium's new technology, InfiPoints is chosen as the tool to view and edit huge point cloud data with high performance, which allows them to grasp the present layout and plan the remodel of production lines.

3.2. Canon Inc.

It has immensely increased the job efficiency in utilizing and distributing 3D data to the suppliers in the entire group of Canon to introduce high-quality and high-reliability 3D data translation system powered by Elysium ASFALIS. All 3D data distributed to their supplier pass through this system from core PDM system and are translated to various kinds of formats automatically. Canon is using ASFALIS as a 3D data translation engine for the enterprise level PDM system – a common platform for both the Canon and its subsidiaries.

This platform consists of two systems (Figure 3). First system is to translate the CAD data from the designing on demand to IGES or other general formats to utilize the data. Users can control all these translation and distribution processes via Web-based interface. The other is to translate the data to multiple formats automatically when the data gets released from the PDM. The translated data is utilized at various divisions in Canon, or sent to the data distribution system for suppliers.

This also allows the coexistence of two CAD systems during the migration period. ASFALIS Translation server automatically translates huge volume of 3D data in the legacy CAD format to the new CAD format accurately as solid models. Regarding the data translation between two CAD systems, Elysium has also developed an engine for 2D-3D associativity translation which keeps 2D drawing data updated as the changes being made on the associated 3D data. Associative drawings preserve sheet layouts, drawing views, annotations and dimensions that will be updated when associated 3D parts or assemblies are changed. Moreover, Elysium provides a tool to validate 2D drawings translated from the legacy CAD format to the new CAD format. It works as a plug-in on NX, the new CAD system, so that designers can validate 2D drawings and modify if necessary within NX.

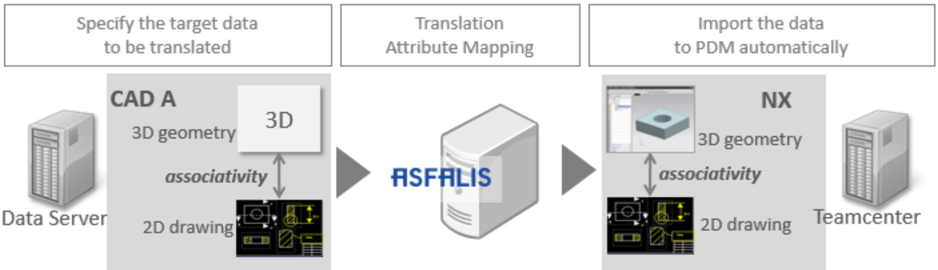

Figure 3. Data Translation System ASFALIS.

3.3. Nissan Motor Company

ASFALIS adapters allow all patterns of translation in Nissan so that users can leverage any CAD data freely. In fact, ASFALIS enabled to translate 3D data between INCAM* and several CAD systems, such as I-DEAS, NX and CADCEUS. A large amount of data can be converted and delivered properly. Thus, ASFALIS have built up high-quality 3D data translation and distribution system for every process (Figure 4).

Numbers of control and delivery systems had been used as many as the number of 3D tools adopted in the production technology field and data quality differed from tool to tool. Because of the difference in PDQ, translation accuracy was frequently disrupted. To solve these problems, Nissan launched new project to shift to totally new workflow of translation at the same time as replacing its standard CAD system from I-deas to NX. On this project, ASFALIS was chosen to consolidate the company-wide translation system to achieve high accuracy and great stability on the performance.

ASFALIS has allowed users to perform all patterns of translation in any CAD format. It also enabled to control concurrently running file translation processes. As this ASFALIS-based system is incorporated to the intranet, employees in domestic branches are able to access ASFALIS to execute translation. The results of translations are automatically delivered to a specified branch in a specified format. Even if different paths are necessary between approved data and data under consideration, it won't be a problem because users can change settings as required. And, once the settings are ready, ASFALIS automatically translates data and distributes the result as needed.

Today, every progress of translation and distribution is thoroughly visualized. Of course, the quality of results of translation is admirable and stable. ASFALIS has significantly improved the efficiency of the company-wide workflow of data translation and distribution.

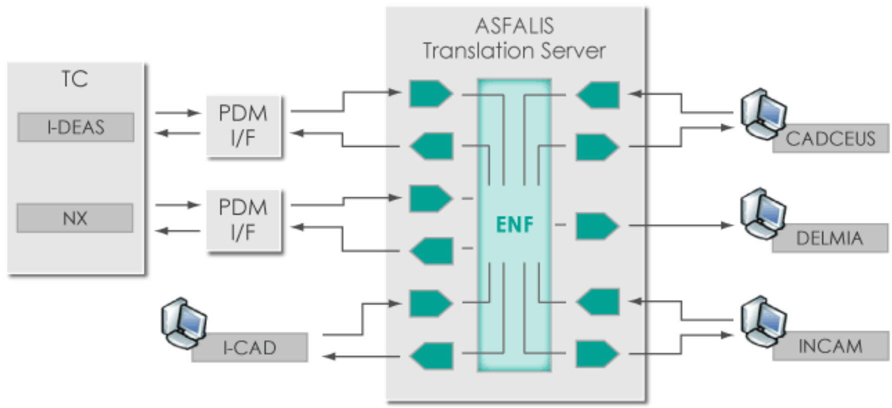

Figure 4. Data Translation System ASFALIS.

3.4. Renault Sport F1

Formula 1 represents the best of the best in motorsport. Renault Sport F1's engine partners similarly represent the cream of the crop. To win against teams such as Ferrari or Mercedes, engines must deliver perfection at every race; engine failure is not an option. Maintaining this level of competitiveness requires the engineering team to know every part precisely. New parts must be a perfect fit and collaboration with suppliers unambiguous.

High performance engine parts are purchased from many suppliers with short lead times. Engineers deliver high quality, ready to manufacture CAD models in the format of each component supplier's CAM software. Data translation must be fast, automated, error-free, and driven by Renault's ERP process.

As each part or assembly is released for production, Renault Sport F1's ERP system communicates with its PDM system to check the appropriate CAD model and send to Elysium's server for translation to the suppliers' CAD format using Elysium's ASFALIS automated translation software. Each model is checked for geometric defects before and after translation. Suppliers use these models to quote prices and delivery dates and to provide feedback about design changes needed for efficient manufacturing. When orders are approved, models are ready to use with numerically controlled milling machines and CMM inspection systems. The translation server stores a profile card for each supplier with the target software and release level.

4. Cloud Solution

Further application case is the cloud where almost each participant can suddenly ask for translation like in a web shop and pay per use, as it happens in a manufacturing supply network. Several collaboration models such as distributed development in heterogeneous environment need to preserve design intent [14]. It's beneficial when this service is offered in a robust environment which facilitates plethora of CAD systems. In our case, all methods including the translation of parameterized feature-based CAD models have been integrated into a fully automated workflow, which is based on the software OpenDXM from PROSTEP (Figure 5).

This commercial software solution is implemented as a supplier portal www.OpenDESC.com, which covers various services for suppliers and OEMs in a collaborative environment: data exchange, CAD model translation, data checking, data management, data release, and operational services. Around 250 companies with different systems, methods and processes have already used this portal for product communication on daily basis across the globe [15]. Around 60 CAD environments are installed and continuously updated upon customer' demand. In case of full service, the whole exchange environment is hosted by PROSTEP. The intention of OpenDESC.com is to relax and reduce the complexity for suppliers by taking and hosting the most critical steps in the product data exchange. Therefore, a high level of verification, traceability and monitoring is achieved, which is endorsed by relevant audits.

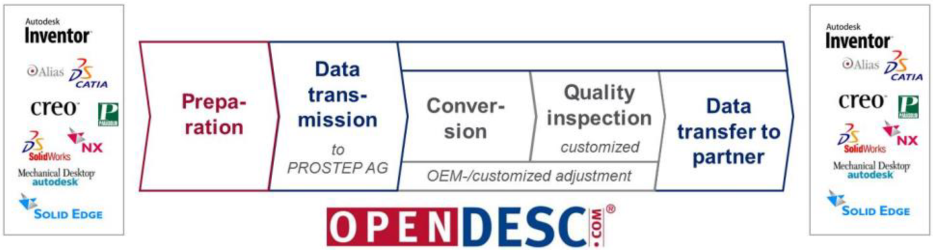

Figure 5. CAD exchange and translation in www.opendesc.com.

5. Summary and Outlook

In this paper, we have highlighted challenges, approaches and achievements in the exchange of parameterized feature-based models between different high-level CAD systems.

Firstly, data models, semantics and terminologies that are used in different CAD systems to represent the same feature are not identical. While generating the neutral CAD representation (STEP or similar to), the translation result can be different because of the terminology and semantics difference. Therefore, the correspondence in a mapping table should be found before generating the neutral representation.

Secondly, one of the well-known problems of data exchange – is the persistent naming problem [6]. It is crucial 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 can cause unexpected errors. Therefore, the utility of hierarchical system models can be considered as a way of flexibly combining such elements by focusing on requisite functionality [16].

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 right exchange of CAD data. However, different systems define and apply accuracy in different ways adjusting appropriate settings during data exchange can become a challenging task.

Besides, five industrial application cases have been briefly described, provided by Elisyium Inc. with their translation technology.

As main challenge for future development remains exchange of knowledge items such as knowledge templates [17] [18].

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