J. Cha et al. (Eds.)

doi:10.3233/978-1-61499-440-4-587

Standardized Approach to ECAD/MCAD Collaboration

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Abstract. Adopting the mechatronics as contemporary engineering discipline the integration of mechanical and electrical CAD (MCAD/ECAD) systems is a big challenge in concurrent engineering because their data models and functionality have been developed continuously further apart. Market research confirms that an integrated tool chain for ECAD and MCAD design is prerequisite for a better mechatronic development process. This paper describes the concept of deep integration for mechatronic products conducted by ProSTEP iViP Association which combines existing standards. Version 3 of the current ProSTEP iViP Recommendation PSI 5 entitled "ECAD/MCAD-Collaboration" provides a comprehensive specification for collaboration between the ECAD and MCAD worlds. A considerable number of vendors have now implemented the underlying data schema and integrated it in the corresponding products. As a result, users can now choose the solutions that best meet their particular needs from an increasingly wide range of efficient systems for collaborative product development within the ECAD and MCAD fields.

Keywords. Mechatronics, mechanical CAD, electrical CAD, integration, collaboration

Introduction

Nowadays manufacturing industry is global, both in terms of customers spread across multiple regions (from mature and emerging markets) and competitors and suppliers scattered around the world. The issue from a product manufacturer’s perspective is how to respond to and best satisfy complicated customer requirements while at the same time delivering attractive products at higher quality levels, at the right time, and at a reasonable price. Market leaders appear to have an appropriate answer to achieving these goals through product and process innovation gathering better functionality for their products [1]. In most cases innovative functionality combines many physical principles: mechanical, electrical, optical etc.

However today is a product without mechatronic parts and assemblies hard to found. Cross-domain is standard feature of business. Sensors, drives, controls and automation are typical applications. In response to this call for innovation, manufacturers have accelerated their adoption of electronics. Research report shows that 92 percent of manufacturers now incorporate electronic elements into their products [2].

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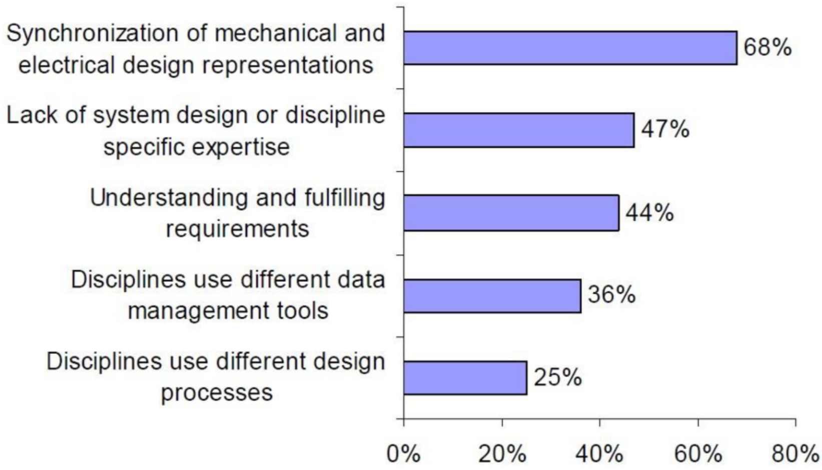

Figure 1. Mechatronic product development challenges [2]

While products become increasingly demanding and complex, so that their mechanics, electronics and software are adjusted with each other must always comprehensive - at ever-shorter leading times and increasing cost pressure [3]. Particularly challenging in this case, are the mobile applications such as automotive mechatronics which are the main drivers for further research and development [4].

As electronics become a more essential component of all products, it is crucial that electrical and mechanical designers communicate on a regular basis to provide that their design changes are coordinated with each other and, thus, eliminate design conflicts. These challenges are only by a concurrent engineering and cope with, especially by developing partnerships. Be exchanged in a globalized world, such collaboration requires not only an effective and loss-free data exchange, but also a clear overview and control what information flows between different disciplines. Thus, the content should be a data exchange on the electrical and mechanical parameters limited so precisely that on the one hand, the common development task can be fulfilled, but on the other hand, the domain-specific issues to be considered separately, and the domain expert knowledge is used optimally.

1. Related Work

Integration of MCAD and ECAD systems is no new issue. There are many attempts in the past to close the gaps between these two worlds. This was not enough, because the data models and functionality of modern mechanical and electrical CAD systems have been developed continuously further apart. Synchronization of mechanical and electrical design representations is recognized as the huge obstacle for any cross-domain integration. Analyzing the basic functionality of both systems based of many criteria for industrial application, important differences become obvious (Figure 2). 3D integration provides a mechanism for space transformation of the traditional planar implementation of integrated circuits into three-dimensional space [5], following the simple rule: the smaller is the available space, the more important is the integration [6].

	mechanical design	electronic design
Education of users	mechanical engineering	electronic engineering
computing of logic	none	schematics/netlist
main functions	boolean operations in order to realize intended geometry and load	component placement, routing in order to realize physically the netlist
presentation of geometry	three-dimensional (spatial)	two-and-a-half-dimensional (planar + high)
engineering functions	structural calculation (FEM/BEM, modal analysis), kinematic analysis, process simulation (Moldflow, NC simulation, etc.)	Design Rule Checks (component, track clearance), thermal, EMC simulation
libraries	standard parts, tool components (geometry/material)	Electrical / electronic components (2D-footprint, height, electrical properties)
CAD-CAM production (examples)	NC drilling, milling, welding, etc.	SMD insertion, pcb drilling, milling
CAD-CAM tools (examples)	injection molding, eroding	stencils, screens, etc.
main supplier	Siemens PLM/NX, Dassault/CATIA, PTC/Creo	Mentor/Boardstation\Expedition\PADS, Cadence/Allegro\OrCAD, Zuken/Visula\CR-5000\CADSTAR

Figure 2. Comparison of mechanical and electronic design

There are four steps in the ECAD-MCAD convergence conceivable (Figure 3). Three steps comprise interoperability with various degree of deepness (loose coupling, tight coupling, PDM integration) between two software systems with fundamentally different data models. One of the main obstacles for such approaches is the appropriate use and processing of 3D data in ECAD system. The fourth step is implemented as an integrated ECAD-MCAD system which fulfills functional requirements of both domains in a monolithic way [7].

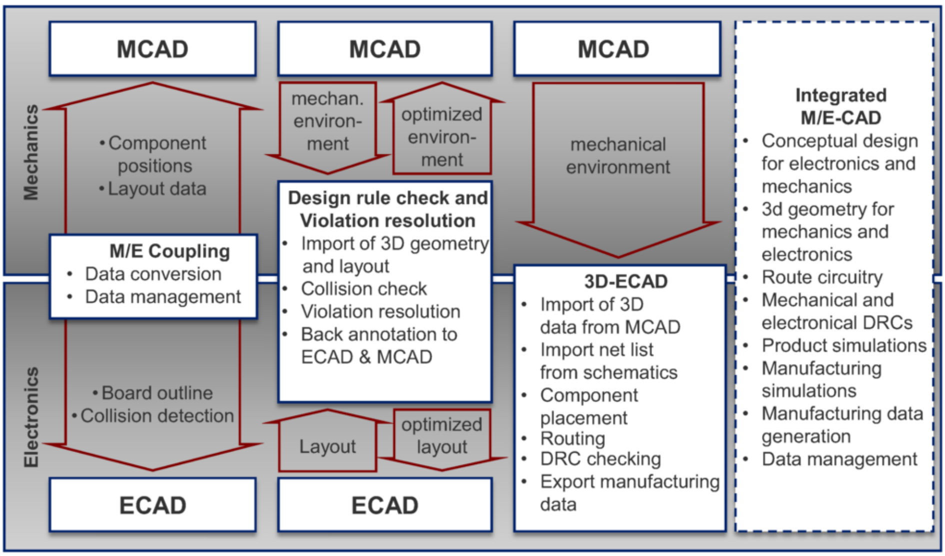

Figure 3. Examples for collaboration of ECAD and MCAD tools

2. Market Challenge

In addition to pursuing a number of strategies for mechatronics development, manufacturers are also addressing the challenge of getting the engineering disciplines to work together with tactics focused on adapting their processes and technology to the inevitable changes [2].

From a process perspective, *Best in Class* versus *Average Companies* both strongly agree that they need to *integrate design processes across disciplines* (90% versus 84%) as well as *develop or reengineer the requirements process* (40% versus 31%). Because both of these tactics span engineering disciplines, they could help resolve integration issues.

Here it is evident that an *integrated tool chain for ECAD and MCAD design* is prerequisite for a better mechatronic development process. The interoperability in terms of a collaboration process on selected ECAD and MCAD objects that might be originally created either in the one or the other CAD environment is an essential requirement. The collaboration process must embed both the creation of a baseline and the common collaborative work on the collaboration model proposing changes where the baseline has been created earlier in the design process. To exploit the most benefit it must be possible that not only the whole data model but also selective parts of it are exclusively usable.

3. Integration Concepts and Solutions

In this section two fundamentally opposite concepts and implemented solutions will be described in detail here: integrated (monolithic) ECAD/MCAD system and interoperability between basically autonomous ECAD and MCAD.

3.1. Integrated ECAD/MCAD System

The integrated CAD system NEXTRA from Mecadtron is an autonomous, comprehensive 3D CAD system for electrical/mechanical integrated product design available with all the known functions for circuit layout design - such as read netlist, placing components, wiring conductor pattern and verify design rules with the multiple possibilities for spatial modeling and visualization in a development tool [7].

The electronics designer gets thereby functions which were previously available only in MCAD systems. He can develop the electronic layout directly in the spatial environment that he can either download from the MCAD system within NEXTRA or even create (Figure 4). A collision-free with respect to the space required minimal design of the electronic assembly from the beginning is ensured.

Nevertheless, if for example changes to the geometry of the case, would be required, the electronics designer may mark the related portions precisely and just play back the housing together with the board and placed building elements, simply to the mechanical CAD system. With the extensive geometric modeling (e.g. Boolean operations such as addition, subtraction, intersection of bodies) and visualization (3D wireframe or shaded representation of the products, dynamic camera) the user has even the possibility to change the geometry of the mechanical system on demand. It can also set all the design steps undo and restore.

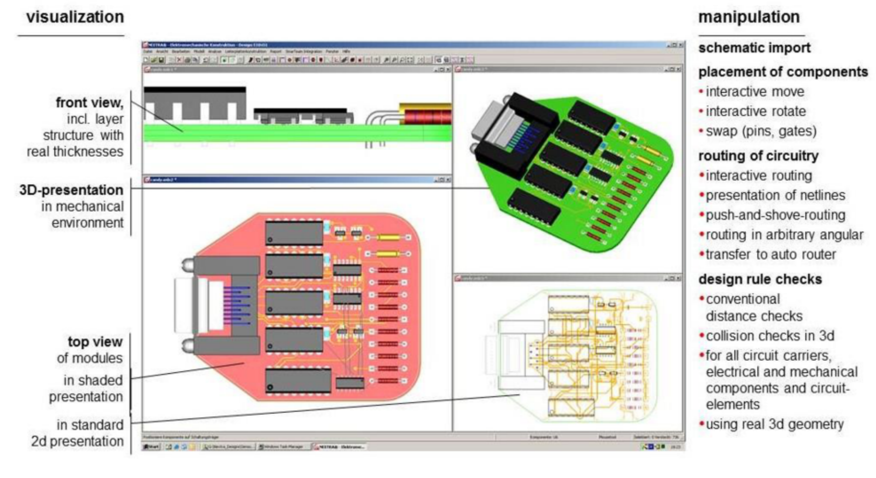

Figure 4. 3D layout development with NEXTRA

After reading of the netlist from a circuit input system, the defined components are displayed three-dimensionally on the screen and can be comfortably moved and rotated by dragging and dropping on all three-dimensionally shaped surfaces (planes, rule or free-form surfaces). Similarly pin and gate swaps are as well as possible the work in the grid. The netlist is shown on the usual connection lines. By clicking on the positions the layout designer can move easily the paths of the conductive pattern, straightforward and pose as needed either as a center line, as a surface contour or even as a solid, including the defined height. He has the option to specify individual areas or generate all aspects of the spatial circuit board manually or automatically, to turn them over to the automatic wiring to an external autorouter.

The layout is always taking into account the technology definitions data stored in a relational database, e.g. trace widths, heights and angles, pad shapes, pad stack definition. All pre-actions are taken online, or are started deliberately checked by extensive design rules that can be set in NEXTRA for conditions in space (e.g. minimum distance of a high-frequency line to a metal housing). Technology informations can also enter both centrally and in the workplace or from external systems (from other CAD systems or libraries, and from external suppliers or customers) can be imported directly. The modeling functionalities include also design modules for specific board technologies and validation procedures. In addition to the technology database a component library is provided, which allocates both electrical properties and the complete 3D geometry in structured manner. The connection to the EDA Systems from Mentor Graphics, Cadence and Zuken is available via interfaces for netlist, library, autorouter, autoplacer and 2D layout. The integration in the mechanical CAD systems such as CATIA, Creo, SolidWorks or NX runs also via system-specific or open interfaces (IGES, STEP, SAT).

Apart of all advantages in term of integration, this monolithic approach discovers serious weakness on horizontal integration if further CAx tools are deployed for the same task. And if the master is not the integrated tool, then methods of the ECAD/MCAD collaboration have to be used to check the consistency of the presentation of the master and the integrated model. Higher expenses through training, support, and administration must be taken into account.

3.2. ECAD/MCAD Collaboration

First attempts for such solution were based on proprietary interfaces or Intermediate Data Format (IDF) [8] driven by raising mechatronic product development. Two approaches came from leading CAD vendors: „Enabling Mechatronics Product Development with Digital Prototyping” from Autodesk [9] and „ECAD-MCAD Collaboration Solutions“ from PTC [10]. These approaches elaborate the three key engineering activities within mechatronics product development: Multi-Disciplinary Design and Engineering, Managing Communication and Workflow, and Effective Early Validation.

It explains also the native integration of Autodesk’s ECAD and MCAD products. AutoCAD Electrical passes electrical design intent information for cables and conductors directly to Autodesk Inventor to automatically create a 3D harness design. Autodesk Inventor users can pass wire-connectivity information to AutoCAD Electrical and automatically create the corresponding 2D schematics.

The weaknesses of proprietary approaches and solutions were picked up by the ProSTEP iViP Project Group ECAD/MCAD-Collaboration which consists of about 20 delegates from industry, IT vendors and academia to specify a data model based on ISO10303 AP 210 and AP 214 and a related XML schema for implementation. Furthermore, services were defined which enable the exchange of information between that ECAD and the MCAD system on basis of the defined data model. The aim of this development was an efficient collaboration between ECAD and MCAD developers to provide a new method for communicating and exchanging information between both domains electric and mechanics. Thus, it yields an ECAD/MCAD Recommendation is to specify the data models and protocols required to enable collaboration between the domains ECAD and MCAD - process oriented and based on existing standards [11].

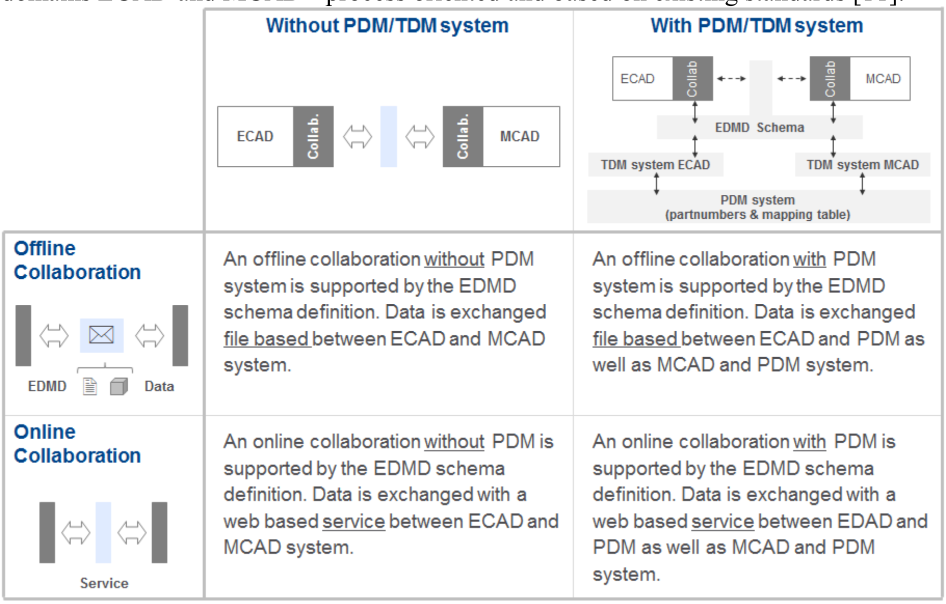

Figure 5. Practical scenarios for EDMD collaboration

The data model specified to enable mandatory collaboration between ECAD and MCAD domains is based on terminologies derived from STEP AP 214 (Core Data for Automotive Mechanical Design Processes) with enrichments using STEP AP 210 (Electronic Assembly, Interconnection and Packaging Design). To facilitate implementation, the data model specified in the Unified Modeling Language (UML) has been made available as an XML schema (EDMD schema).

This recommendation describes collaboration processes with and without the control of a PDM or TDM system. Figure 5 gives an overview of the scenarios which are supported by the EDMD schema.

In principle the EDMD schema supports the following four constellations: either online/offline collaboration or with/without PDM/TDM system. It was decided within the project group to focus initially on seven modular use cases with mutual dependencies, which are depicted in Figure 6.

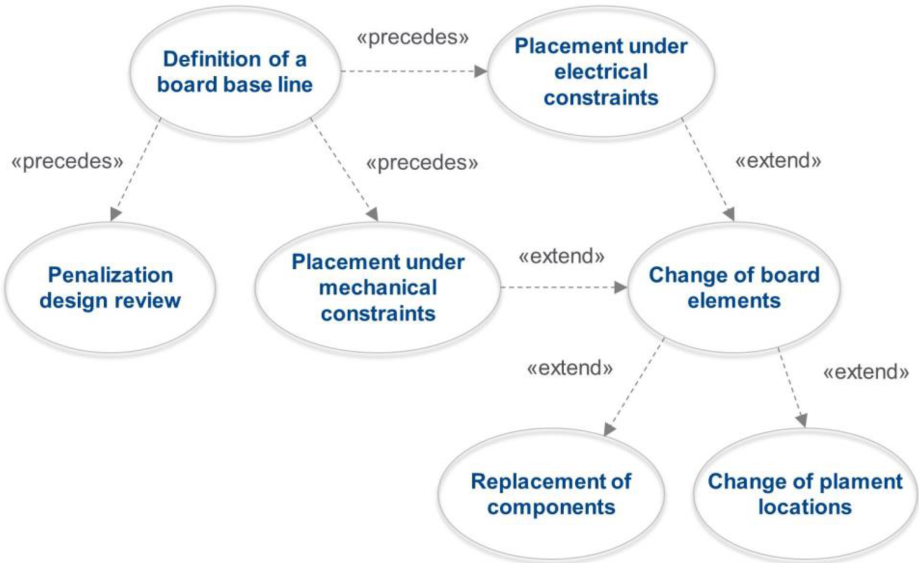

Figure 6. Dependencies between use cases in scope of implementation

In the descriptions of the use cases, mention is made of “actors”. In this context, actors can be either human users of a system, a machine, software or any system. Anything that interacts with the system within the context of a use case is referred to as an actor.

The PDM system is responsible to store and provide the data which is necessary within the collaboration. The PDM system is not responsible to steer the collaboration process. The collaboration process takes place between the ECAD and MCAD system and their collaboration modules. An important role within the collaboration process plays the management of the collaboration sandbox. In the collaboration sandbox the data used within the collaboration is stored. Each system participating in the collaborations needs and provides data in the collaboration sandbox. The physical representation of the collaboration sandbox differs if the collaboration is an online or offline collaboration.

In an online collaboration the collaboration sandbox is a central "file system" in which the PDM system checks out the native data which is used in the collaboration. It is a snapshot of the data in the collaboration space. After the collaboration the data stored in the sandbox is deleted. The PDM/TDM system takes care of the collaboration sandbox management within an online collaboration.

Within an offline collaboration the collaboration sandbox exists locally in each location. No centralized managed storage is available because the EDMD schema data is submitted with an offline medium such as email etc. The management of the collaboration sandbox is done by the user himself or by the participating collaboration systems.

The TDM system of the ECAD world only knows the electrical structure of the product. It has no information about the mechanical world. The TDM system of the MCAD world only knows the mechanical structure of the product. It has no information about the electrical world. Only the PDM system has - with the information about the part numbers and a mapping table - the information about the mechanical and electrical structure of the product. For this reason the PDM system is responsible to provide the overall structure information used within a collaboration either to the TDM systems or directly to the participating ECAD or MCAD systems.

Creating ECAD representations and 3D representations of electrical and electromechanical components is an enormous workload. The goal is to provide a standardized component library specification of components within the EDMD Schema. This chapter documents the use cases for an EDMD Schema supported library management. The documentation is based on the standardized use case description. The following three use cases were defined and will be discussed in detail by the following chapters: Using library information within collaboration, Cross domain library to library data exchange, Provision of library data from supplier.

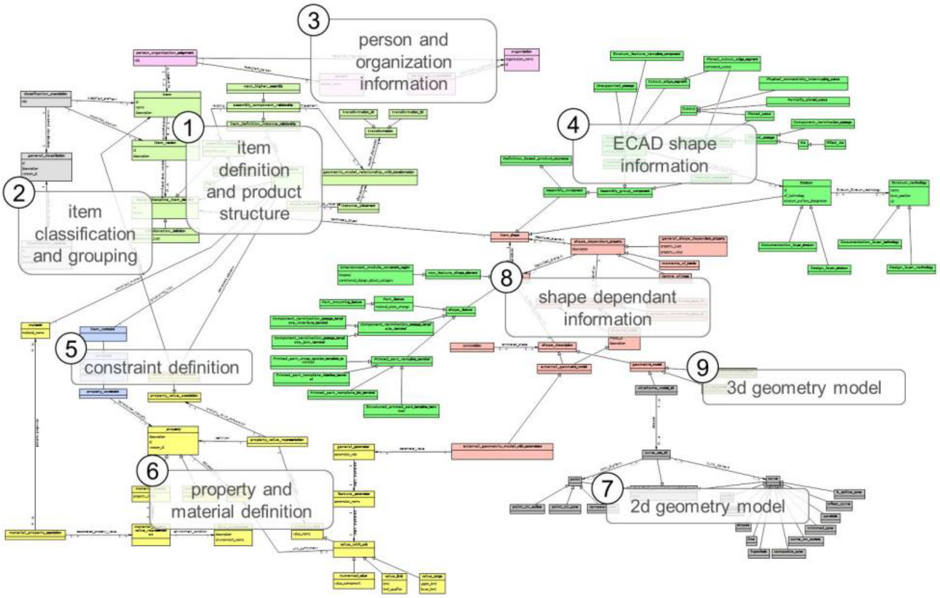

Figure 7. Application-driven data model

The application driven data model is intended to describe the requirements relating to ECAD/MCAD collaboration from the view of the user. In addition, it should also be able to support the functionality required by the user within the framework of an ECAD/MCAD collaboration.

The application-driven data model is divided into different functional areas, which are referred to as “packages”. Figure 7 provides an overview of the developed data model with the nine currently defined packages (enumerated 1 – 9) which consist of singular objects.

Three functional scopes have been defined to support the different steps: basic component related collaboration (packages 1, 2, 3, 6), advanced shape related collaboration (plus packages 4, 7, 8, 9) and constrained based collaboration (plus package 5).

The actual interconnection of CAD systems is performed using a protocol which is based on the implementation-driven data model. This model was created as an XML schema and is shipped as an extra zip archive, which is also part of the recommendation but not part of the printable piece of the recommendation.

The EDMD protocol is based on the implementation-driven data model and serves to transfer change information between the systems involved. The messages in the EDMD protocol are defined in a general manner and can be exchanged between the systems involved using any technology (P2P approach). This means that the use cases involving synchronous and asynchronous collaboration can be represented in a 1:1 configuration or a 1:m configuration. The subject of the current recommendation is the 1:1 configuration.

The representation of message exchange via Web services is also covered by the recommendation. The protocol interfaces are described in WSDL. WSDL is part of the recommendation and can be found in the zip archive including the xml schema definition of EDMD Schema.

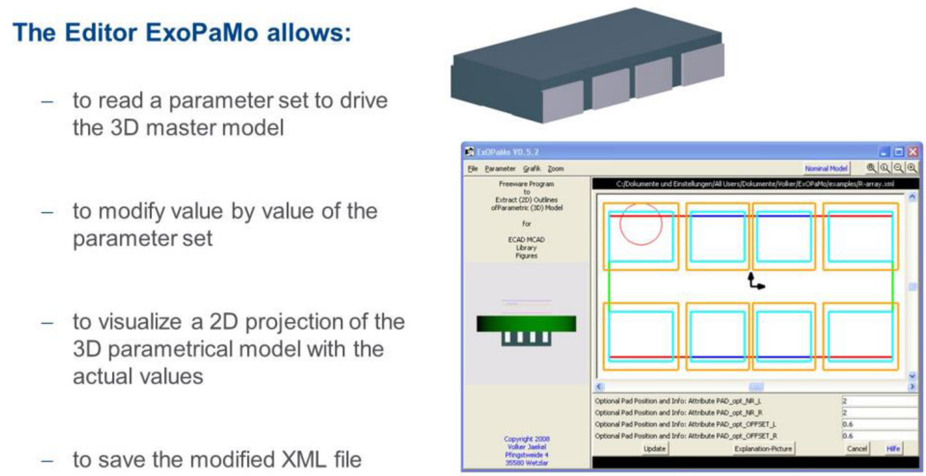

Figure 8. Exemplary implementation at Continental

An implementation guideline and conformity criteria are also available. The guideline simplifies the task of programmers responsible for implementing the ECAD/MCAD data schema, while the defined criteria are intended to ensure interoperability between the various applications.

3.3. Implementation

Six leading suppliers of ECAD and MCAD systems have now integrated customer solutions based on the ECAD/MCAD data schema (known as the "EDMD schema" for short) in their software. In addition, Continental has itself internally implemented parts of the Recommendation for the management of 3D master models for library components (Figure 8). Further implementations are expected too.

4. Conclusions and Outlook

Tight collaboration among electrical and mechanical designers throughout the product creation process of mechatronic products is required to improve product designs and to support additional product innovation. Two integration concepts of ECAD-MCAD are highlighted and discussed.

Benefits that are achieved by ECAD-MCAD integration include faster engineering change resolution, more functionally valid designs, prediction of product behavior, and prevention of unnecessary errors. When ECAD-MCAD integration takes a central role in the product development process, a number of positive impacts rises. The supporting technologies and practices should be implemented along with appropriate cultural changes and training measures to most effectively take advantage of tight ECAD-MCAD integration within an enterprise's particular business strategies.

As collaboration on processes such as collaborative design and engineering change is very important and beneficial, the full impact of ECAD-MCAD integration will not be obtained until the tools allow a much broader collaboration across disciplines that fulfills the need for complete product development, simulation, and validation. The long-term goal will be to support simulation of the complete system's interactions including those among software, electrical, and mechanical components of a product.

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