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APPROACH FOR A DATA-MANAGEMENT-SYSTEM AND A PROCEEDING-MODEL FOR THE DEVELOPMENT OF ADAPTRONIC SYSTEMS

Roland Nattermann
Technische Universität Darmstadt
Department of Computer Integrated Design
Darmstadt, Germany
nattermann@dik.tu-darmstadt.de

Reiner Anderl
Technische Universität Darmstadt
Department of Computer Integrated Design
Darmstadt, Germany
anderl@dik.tu-darmstadt.de

ABSTRACT

Existing proceeding-models for the development of mechatronic systems intend a mostly independent development of single components, like the mechanic structure, the electronics, etc., starting from a combined over-all-model. Following the understanding of adaptronics as an advancement of mechatronics in the LOEWE-Center AdRIA (AdRIA – Adaptronic - Research, Innovation and Application), a clear division of the development is not advisable, because of the high structural integration of adaptronic systems. Because of this, it's necessary to develop the whole system by using a permanent alignment of values between the single components. This high grade of data transfer and the high number of relations between the components lead to a complexity that can only be handled by the use of a Data-Management-system. An approach for a Data-Management-System for the development of adaptronic systems by the Department of Computer Integrated Design, as part of the LOEWE-Center AdRIA, intends to extend the functionality of existing Product-Data-Management-Systems. The idea is to model the over-all system in the Data-Management-System at first, using the partitioning of the system into the five elements of active structures: excitations, structural components, actuator systems, sensor systems and signal processing. Furthermore the characteristic parameters of single components and the correlations between these parameters are captured. In addition the requirements of the adaptronic systems are captured and deposited in the Data-Management-System (DM-System). An integration-layer is used, to integrate the data and models of the different disciplines to the DM-System and to the generated over-all model, during the development of the adaptronic system. The database of the DM-System contains a standardized over-all-simulation model of the adaptronic system, which uses the same partitioning of the system to the different elements as the over-all-system model. The consistent structure of the system-model, simulation-model and integration-layer is used for an automated over-all-simulation of the adaptronic system. Using the automated over-all-simulation changes in the adaptronic-system-behavior can be calculated, when changes in single components become available. Using the deposited requirements, these changes can also be valued. An analysis of existing proceeding-models for the development of mechatronic systems shows, that they are only partly suitable for use in the given approach. Therefore a new proceeding model was developed as an advancement of existing models. The new model shows an equitable solution for the development of adaptronic structures by using Data-Management-Systems.

INTRODUCTION

The development of mechatronic systems needs the cooperation of completely different disciplines, like mechanics, electronics and software development. These disciplines use different models based on different views and data.

Different proceeding models for the development of mechatronic systems, like the V-Model in [1], have been developed. The aim of these models is the effective cooperative development of mechatronic systems. According to the V-Model the development of mechatronic systems should be separated into the development of single components, which should be developed parallel in the single disciplines and then be integrated to the overall system.

Studies in the automotive industry showed that there are a lot of problems with respect to the integration of the discipline-specific components, because of the lack of communication of results and data during the parallel development [2]. To solve the problems about the integration, ProSTEP recommends the alignment of results between the different disciplines on given times during the detailed, parallel development [2].

The high structural integration of single components in adaptronics prevents an independent development of single components. To prevent an increase of the problems in system integration it’s necessary to develop a concept to match the models and data between the different disciplines while developing the detailed components [2].

In the past some approaches were made to use software for the alignment of discipline-specific results during the development. Bellalouna uses SOA-concepts for an integration of discipline-specific data [3] (SOA – Service Oriented Architecture [4]). According to [3] adapters are used for the SOA-based integration of data in a mechatronic platform, using an interdisciplinary mechatronic data-model.

Tabbert recommends the use of parameters to match the results and data between the involved disciplines [5]. Therefore Tabbert suggests the use of the data-model of “SimPDM”, which includes parameters and properties and the relationship between them [6]. Tabbert also recommends a parametric requirements-management [5], to detect changes in the output-values and their effects on the different disciplines.

Herold, Jungblut und Kurch [7] developed a model for the simulation of a whole active system using the mathematical software MATLAB Simulink. In this model they divide the system into five parts, belonging to different disciplines. These parts are excitation, mechanical structure, sensor system, actuator system and signal processing.

In the present paper a new approach for the permanent matching of results between the disciplines in the development of adaptronic systems is made. The developed approach is based on the use of a central data-management-system. The data-management-system uses a data-model that depends on the “SimPDM”-model [6]. Within the data-management-system (DM-system) the adaptronic system is modeled, using the partition developed by Herold, Jungblut und Kurch [7]. Furthermore the data-model allows the capturing of characteristic parameters of the single components and the correlations between these parameters in the system-model. In addition the requirements of adaptronic systems are described and deposited in the data-management-system (DM-System).

Also an automated simulation of the active-system is a component of the approach, using the model of Herold, Jungblut und Kurch [7] as part of the release process. With this automation the changes in the adaptronic-systems behavior can be detected, when changes in single components become available.

The present paper also includes a new proceeding model for the development of adaptronic systems, which includes the use of a central DM-System and the permanent alignment of results between the specific disciplines. The approach provides, in opposite to the V-Model, an integration of discipline specific solutions and the permanent alignment of results during the parallel development of components, using the system modeling of the DM-System.

ADAPTRONICS IN ADRIA

The AdRIA-Center was founded by the German federal state Hessen in 2008 as part of the LOEWE-project (LOEWE – state initiative for the attainment of scientific excellence). The AdRIA-Center is a cooperation between TU Darmstadt, the University of Applied Science Darmstadt and the Fraunhofer institute LBF. The target of the center is research of adaptronics in scientific depths and width [8], [9].

The development of mechanic systems aims at a construction, in which the behavior of the mechanic structure follows the specific requirements. An example for this is the construction of the Euler’s column. During the construction the column is defined for the endurance of a given load without braking.

In opposite to the development of mechanic systems, the mechatronic uses a control circuit, consisting of actors, sensors and controllers, in addition to the mechanic structure [10]. Figure 1 shows the Euler’s column as a mechatronic system. The use of the control circuit affects the systems behavior in a way, that the column can endure higher loads without breaking.

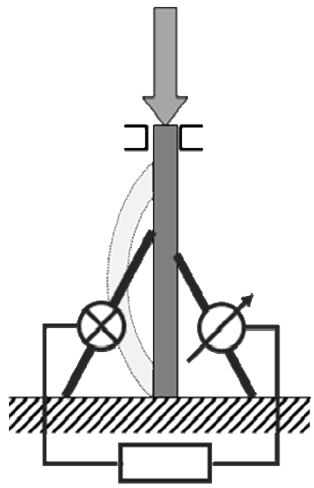

Figure 1: Euler's column as a mechatronic system [11], cf. [12]

The actors, sensors and controllers in Figure 1 are not parts of the original mechanical structure, but affect the system from outside of the system. If the control circuit is shut off, the system is still viable, using only the original mechanical structure.

Regarding the interpretation of adaptronics in the AdRIA-Center the control circuit is not an addition to a given mechanical system, but integrated to the mechanical structure using multifunctional materials [8], [9], [13].

Figure 2 shows the Euler's column as an adaptronic system. Because of the structural integration of the control circuit into the mechanical structure it is not possible to "shut of" the electronic parts in a way, that the actors and sensors are no longer involved into to the system.

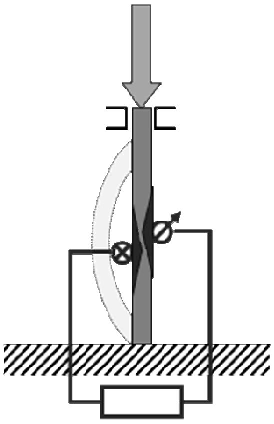

Figure 2: Euler's column as an adaptronic system [11], cf. [12]

CONCEPT

The concept for the central DM-System for the development of adaptronic systems is based on the idea of using different layers as shown in Figure 3. These layers contain the PDM-functionality, the system modeling and simulation and the integration of discipline specific results.

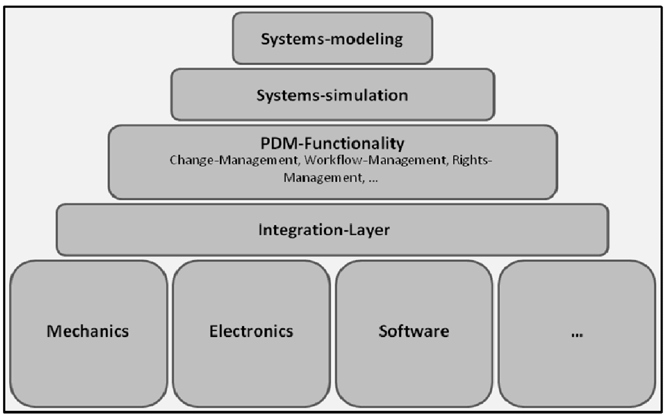

Figure 3: Layer-model for an adaptronic-data-management

PDM-Functionality

The central layer of the DM-system is a common Product-Data-Management-System (PDM-System), which provides all of the "regular" PDM-Functions, i.e. rights-management, user-management, project-management, etc. Because of the use of an existing PDM-system and its integration into the adaptronic DM-System these functions can be assumed without a reimplementation. The integration and use of a common PDM-system is possible, because the general content of the product specific data of adaptronic systems is not different from conventional systems.

System modeling

The top layer of the model shown in Figure 3 contains the modeling of the adaptronic systems. Therefore the DM-System uses a data-model, which is build upon the model developed by Malzacher [14]. This data-model disassembles the structure of an active system in the way defined by Herold, Jungblut und Kurch [7], who disassembled the systems into the sections excitation, mechanical structure, sensor system, actuator system and signal processing. For the modeling of the active system structure theses sections can be composed by more than one element. The data-model of the DM-System also enables the possibility to model an active structure as a combination of other structures (Figure 4).

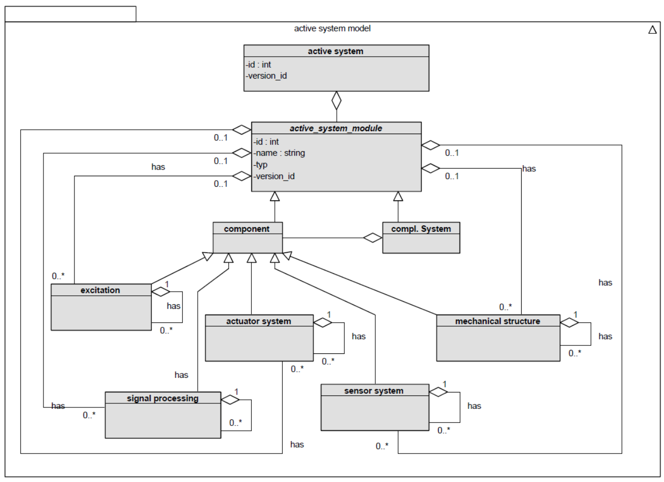

Figure 4: Data-Model for an active system structure (cf. [7])

The different elements of the active system shown in Figure 4 are realized by an optional count of components which are allocated to the specific elements during development. Because of the multifunctional characteristics of adaptronic components the data-model allows for allocating a component to more than one element of the system structure.

An additional part of the system-modeling is the definition of system properties, parameters and their relationships. Therefore the property-section of the SimPDM-data-model [6] was used, which contains the possibility to associate single components of the system with a set of properties. These property-sets may consist of any number of properties. For the property-modeling a variety of different property-types can be used, which can be connected to a number of specific parameters. In addition, the modeling of relations between the properties and property-sets is provided within the data-model.

Figure 5 shows the integration of the property-modeling in the data-model of the DM-System.

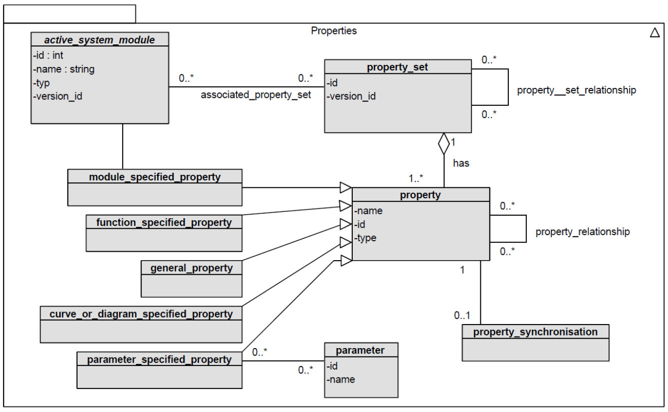

Figure 5: Data-model for the property-modeling [cf. 6]

The third part of the system-modeling is the definition of system requirements. The definition of system requirements is similar to the definition of properties and their relationships. Within the data model therefore an appropriate section, similar to the property-modeling, was inserted.

The modeling of requirements is realized in a RIF-compliant format. The RIF (requirements interchange format) is a standard representational format for the description and exchange of requirements, which was developed by the HIS (Hersteller Initiative Software), a manufacture initiative for the development of software in the automotive industry [15]. Main objective of RIF and of its inclusion into the data model of the DM-system is the exchange and alignment of requirements between different manufactures and disciplines involved in the development process. Therefore the data-model of the DM-system uses the class diagram for a RIF-compliant modeling [16].

According to the data-model requirements can be associated to each other and to single properties and parameters. By combining the requirements with properties and parameters the data-model meets the challenge for a parametric requirements-modeling demanded by Tabbert [5]. In addition an automated alignment between the requirements and the properties within the DM-System is possible. Figure 6 shows the integration of the requirement-modeling in the data-model of the DM-System.

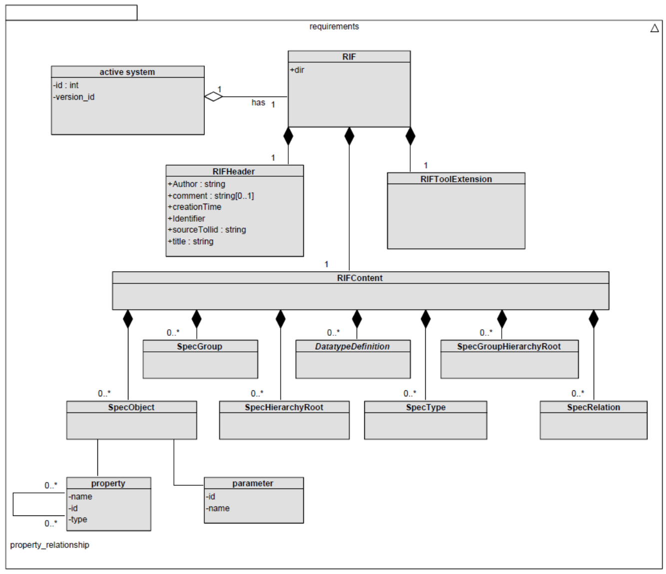

Figure 6: Data-model for the requirement-modeling (cf. [16])

System simulation

The simulation of the system-behavior is performed based on the model developed by Herold, Jungblut und Kirch [7]. Therefore a standardized version of the MATLAB-Simulink-model was developed, which is stored in the database of the DM-system. The model is initiated for each adaptronic system to be developed.

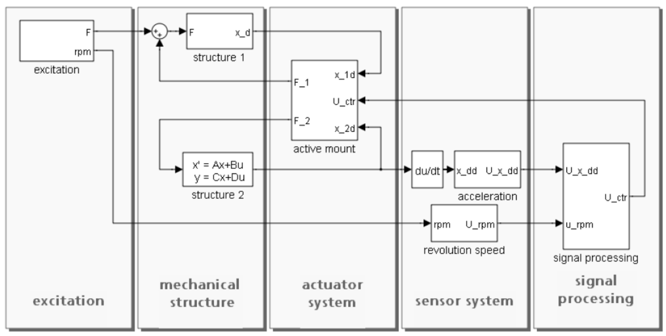

Figure 7: MATLAB-Simulink-model of an active system [7]

For the use of the automation, the system-simulation was integrated in the product development process to represent the central core of cross-discipline development. Thus, the results of all disciplines involved in development are combined in the MATLAB-Simulink-model.

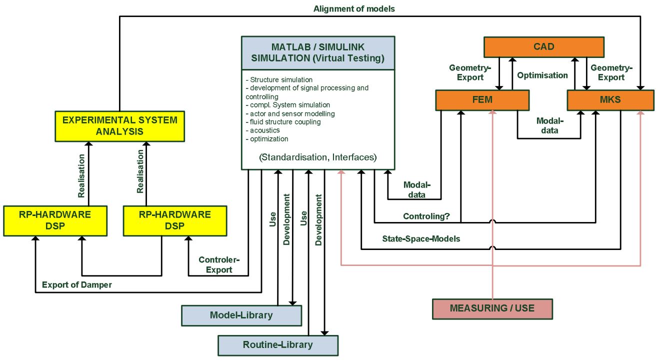

Figure 8: Integration of the System-simulation in the development of active systems [7]

The distribution of the system in the data-model and the MATLAB-model is consistent. Therefore the different components stored in the database of the DM-system can be assigned to respective areas of the MATLAB-model.

Then the parameters and properties, which are stored in the database and connected to the components, are read and inserted in the MATLAB-Simulink-Model. After the adaption of data the model can be passed to the MATLAB-solver. Then the Output-desk of the simulation and the system-behavior describing parameters are read. These parameters are connected to the current version of the active system and are stored in the DM-system as meta-data.

To ensure that the system simulation is performed, the automation is integrated in the DM-System in particular into the release process of new or changed components. Thus, the simulation is automatically performed prior to release and the user is informed about the impacts on the overall-system through the presentation of the simulation and component specific results. This is to detect necessary changes in other components or discipline as early as possible.

This is further conducted by the cross-disciplinary modeling of the properties and parameters. By modeling the relationships between the various properties the overall effects of changes can be evaluated and necessary adoptions can be detected.

Integration layer

The integration of discipline-specific models and data in the adaptronic DM-System is realized through an integration layer. The integration of the relevant records is performed by connecting with software and database solutions used in the respective technical disciplines.

There are two possible approaches for the realization of the integration layer. The first solution is an integration platform, which uses a number of standardized connectors for the communication and data transfer with the specific software solutions for different technical disciplines. An advantage of this solution is that only one service has to be used for data-integration. A possible disadvantage could be the number of needed connectors which increases with the number of software solutions used in the technical disciplines.

For the handling of a huge variety of systems during the integration the possible use of the SOA concept for the connections with specific software solutions in the technical disciplines by using individual service programs, as shown in [3], could be an appropriate approach.

The main hypothesis of SOA is that information technology infrastructure subordinates to commercial interests and processes [4]. Therefore the SOA-concept aims at the conception of specific applications as services. The software and hardware of these services are arbitrary deployed and combined for the integrated support of business processes [17]. For the use of services the specific types of hard- and software used in the processes are unimportant [18].

According to the concept, the communication between the DM-System and the specific software systems and database solutions of the technical disciplines is supported through the use of services. Therefore the functions of the respective software systems are provided by standardized services using appropriate adapters [19].

Although the type of the integration and the specific software solutions used in the different technical disciplines are still not clear, the overall integration of discipline specific data is an integral component of the data model of the DM-System.

Because of the high structural integration of adaptronic systems and the multifunctional character of adaptronic components, the data-model also takes into account the additional option to assign data from different technical disciplines and models to a common component of the system model during integration.

IMPLEMENTATION

For the implementation of the concept, the system SmarTeam from Dassault Systems was selected as the PDM-system. The decision was taken because SmarTeam is considered as an appropriate PDM-system with the required scope. In addition, SmarTeam can relatively easily be extended with additional functions, because it supports provides the customizing to systems and internal solutions of the user.

Current status is an implementation of the developed data-model into SmarTeam. After completion of the implementation the data-model will be validated. Therefore the dataset of an adaptronic engine bearing will be used. This dataset contains all information, created by all involved technical disciplines during the development of the engine bearing in the AdRIA-Research center.

For the implementation of the automated system simulation, the MATLAB Simulink model developed by Herold, Jungblut and Kirch [7] was adapted in terms of automation. Therefore the script-based input of parameters and settings was changed to the use of *.mat-Files. A *.mat-File is a MATLAB internal data type, which contains parameters and values and which can be directly interpreted by the MATLAB-solver.

In a further step, the actual automation of the simulation is generated. For this, first a user interface was created, in which the respective parameter values are first entered manually. With this interface, the automated input of values, the automated execution of the simulation and the analysis of the output-desk has been implemented.

After completion of the implementation of the data-model, the automated simulation will be integrated into the release process of SmarTeam. Therefore, the automation will be changed by using the needed values directly from the database of SmarTeam instead of the manual input.

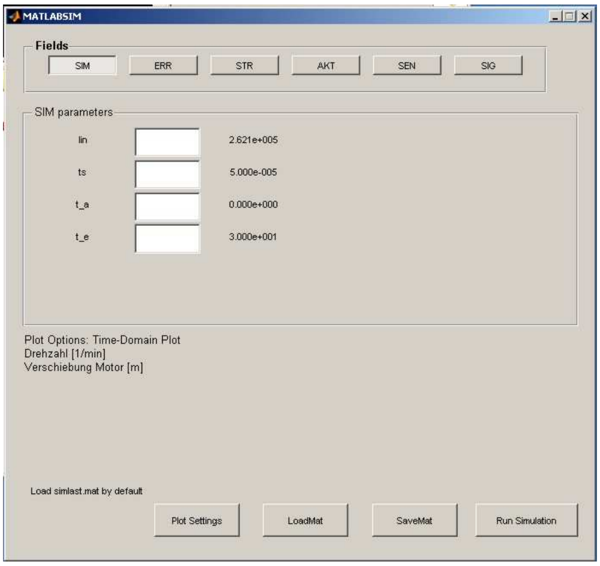

Figure 9: User interface input of parameters

For the implementation of the integration layer currently a study of the software and database approach used in the development of adaptronic systems is conducted. During this study, all technical disciplines involved are examined concerning not only the used software, but also the different system models, used data, output and existing workflows. After this study a decision will be made whether the integration layer can be implemented as an overall platform or if a number of small, discipline and software specific solutions, following the SOA-concept, have to be used.

A PROCEEDING MODEL FOR THE DEVELOPMENT OF ADAPTRONIC SYSTEMS

In the existing proceeding models for the development of mechatronic systems, a largely parallel, independent work of the specific technical disciplines is propagated [1], [10], [20]. There are some approaches to complement the existing models with different software-solutions for the alignment of results [3], but studies show that there are still great problems in the industry during system integration of independently developed components [2]. Moreover, no general proceeding model for the development of adaptronic systems does exist.

Therefore, in the following an appropriate approach for a proceeding model for the development of adaptronic systems is presented. Main target of this model is the permanent alignment of results between the different technical disciplines. To involve a rejection of the model by the users of specific disciplines, the internal processes of the technical disciplines should stay untouched.

The developed approach can be devided into five steps.

System analyzing and work distribution

In a first step the adaptronic system to be developed is analyzed. Then the requirements of the system and the work packages are structured and distributed to the technical disciplines. The concrete steps are similar to the V-Model for the development of mechatronic systems in VDI 2006 [1] or the concretization of the V-Model developed by Bender [20].

First drawing up of discipline-specific solutions

In the course of a first design of discipline-specific solutions a general dimensioning is made. Main Target of the first dimensioning is not a detailed solution, but just a containment of the used systems, models and components.

After this an analysis of the specific properties and parameters is conducted. During this the analysis of dependencies between properties and parameters is of particular interest. Also of particular significance is an analysis of the interfaces between the specific technical disciplines. Therefore a separated consideration of the properties and parameters, which are needed for the determination of the systems behavior or of different properties is performed. At the same time the opposite case must also be considered. In this case the properties and parameters, which are needed as an input for other disciplines have to be detected. At this time the specification of the dependences between the properties and parameters is only qualitative. A quantitative over-all analysis takes place during the cross-discipline integration of the discipline specific solutions.

Integration and system-modeling

After the initial interpretation of discipline-specific solutions and the analysis of properties, parameters, and their relationships the first step is system integration. In this integration the adaptronic system is modeled using the model for active systems described above. Here the system is modeled in the central DM-System. Thereby the adaptronic system is derived into the described elements and the technical discipline specific solutions are linked with different elements, using n to m relationships. With these relationships a discipline specific solution can be linked to different elements or one element can be linked to different solutions.

After the modeling of the adaptronic system the description of the system properties and parameters is required. Doing this, the properties acquired in the technical disciplines and their relationships are modeled in the DM-system, using the described parts of the data-model. In addition, the requirements of the system are modeled and associated with the relationships and parameters. Due to the property, parameter and requirement modeling the resulting network can be used for an automated change tracking.

Through an analysis of the resulting property and parameteranalysis network the system critical properties can be detected. These are properties with significant influence on the systems behavior and their changes affect several technical disciplines.

The created model and the network is used for the permanent integration and allocation of results of specific technical disciplines during the following detailed development.

Detailed development of components

After the integration of the preliminary interpretations of the discipline specific solutions and system modeling the detailed development of the individual components succeeds in respective disciplines. In these disciplines, common development methods are used. For reasons of user acceptance, it is not advisable to take other standard or cross-disciplinary methodologies for granted in the detailing.

While this development resulting models and data are saved within the central DM-system and linked to the system-model and property and parameter network. Through change management and system-simulation included in the DM-system, changes in individual components can be analyzed, concerning the nature of changes and their impact on other components and the system performance. Additional appropriate adjustments can be initiated.

Through the permanent matching of the respective results between the different disciplines the subsequent system integration of the discipline-specific solutions will be facilitated in a way that fewer complications arise which requires subsequent adjustments to individual solutions.

The model also gives the opportunity to feed back results which were not identified in the virtual product development but in experiments or tests into the virtual world. Therefore the test results are only need to be entered into the database of the data management system. Because of the created abstract model of the overall system, these results are analyzed with respect to the impact on other disciplines and sent to the appropriate subject-specific methods.

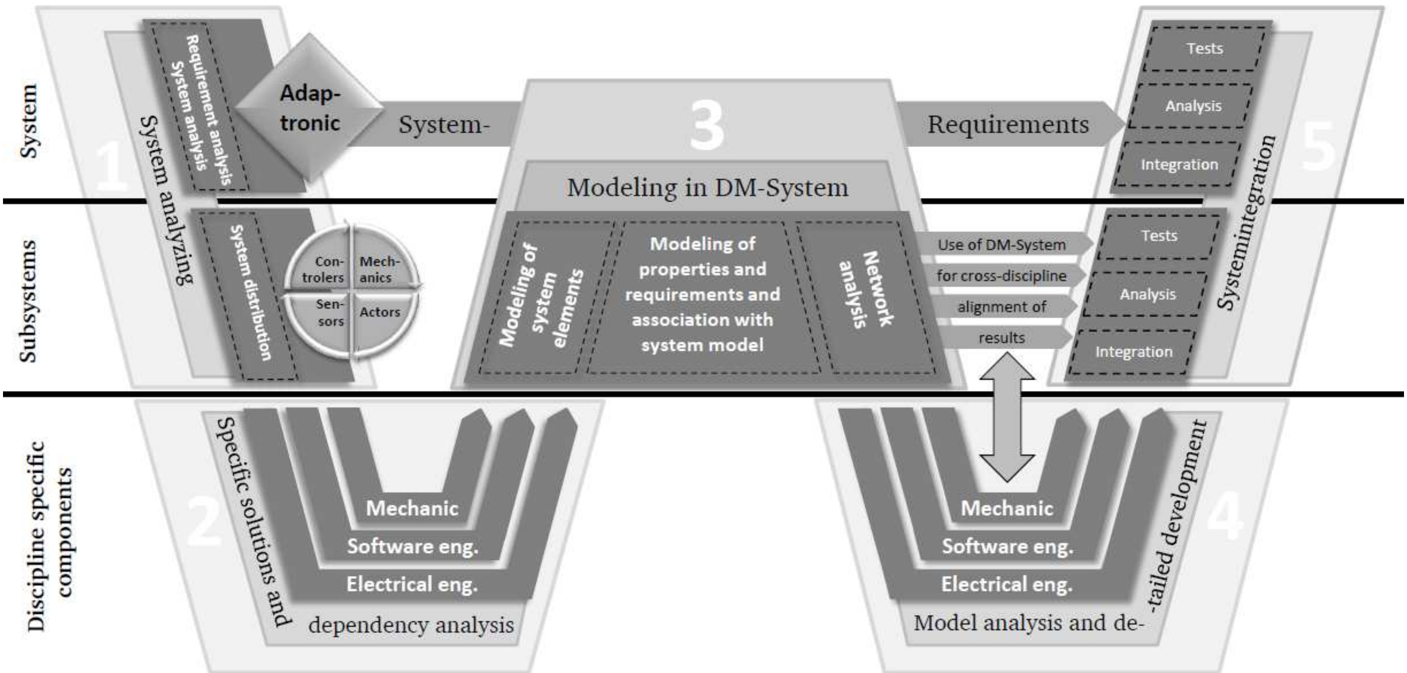

Figure 10: W-model for the development of adaptronic systems

In addition, because of the previous requirements-modeling, an analysis of the system regarding the performance level and a system evaluation can be conducted.

System integration and Analysis

After completion of discipline-internal development of components, a further system integration of subject-specific solutions into the final overall system is carried out. After completion of the integration the final system is analyzed in terms of functional performance and requirements on the system. The exact procedure is similar to the specification of the V-model for the development of mechatronic systems by Bender [20].

CONCLUSION

The development of adaptronic products within economic and qualitative constraints requires a holistic view on the development processes. This requires a coordinated cooperation of the technical disciplines involved.

The approach presented in this paper offers a new model for the coordination and integration of models, parameters and solutions of specific disciplines, like mechanic, electrical and software engineering. The approach defines a layer model, with the layers system modeling, system simulation, PDM-functionality and integration, and is based on the use of existing PDM-Systems as a central DM-system during an adaptronic development process.

The advantage of this approach is to allow the alignment of results from different technical disciplines during an independent, parallel development of components. The alignment is suitable due to the modeling of parameters and properties, as well as their relationships and dependencies, in the central DM-System. The approach also includes an automated simulation of the behavior of the adaptronic system, using data from the different technical disciplines. Using this automation, the influences of changes of components in single disciplines can be detected. According to the approach, the integration of results, models and data from different disciplines into the DM-System is based on the SOA-concepts.

The presented approach is implemented, using the PDM-system SmarTeam from Dassault Systems as a basis for the DM-System and MATLAB Simulink for the automated system simulation. For the implementation of the SOA based integration an analysis of methods and software solutions used in the specific technical disciplines is carried out.

Also an approach for a new proceeding model for the development of adaptronic systems is part of the paper. The new model provides system integration not only at the end, but also during the development of components in technical disciplines. This integration is performed using the central DM-System presented and the implemented system modeling. The proceeding model insists on the use of the DM-System for the cross disciplinary alignment of results during component development. The aim is to avoid development iterations during the final system integration and testing.

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