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Optimization of the development process of mobile machines using a standardized co-simulation

The complexity of mobile machines as well as economic conditions, as relatively low output volumes at a high number of product variants, have a great influence on the development of those machines. In order to operate successfully on the market, there are high requirements concerning the efficiency of the product development process of these companies, which are mainly characterized by small- and medium-sized businesses. One promising approach is to establish close OEM-supplier-networks by using cross-company virtual prototypes. This way, time and cost savings can be achieved. In the joint research project GUSMA, a co-simulation platform, which enables the build-up of cross-company virtual prototypes, has been developed at the Chair of Mobile Machines at the Karlsruhe Institute of Technology.

Keywords

Virtual product development, co-simulation, cross-company, GUSMA, mechatronics

Abstract

Landtechnik 67 (2012), no. 2, pp.122–126, 3 figures, 2 references

The growing product complexity imposes high requirements on the efficiency of the development process of mobile machines – regardless of whether the focus is on detail optimization on component level or whether the development of a complete system is emphasized. On every level of detail of a product, the realization of the corresponding product specification has to be ensured. In order to allow the verification of product functionalities in an early stage of product development, in the last decades, the usage of simulation tools has proven itself successfully. Using these tools, cost intense or dangerous tests with real prototypes can be substituted to a great part with virtual tests. This way, the application of simulation tools can result in time and cost savings during product development.

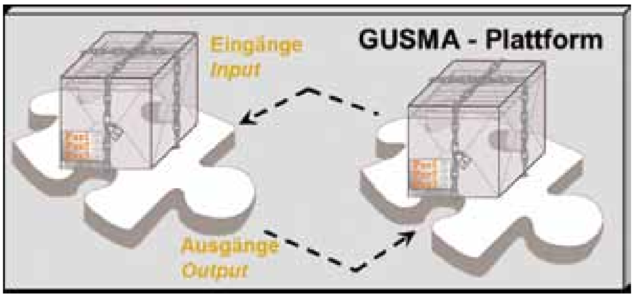
In order to achieve reliable results about a product, which is to be developed using simulation, it is necessary to integrate the know-how of all involved development partners at an early stage of the product development process. Depending on the in-house manufacturing penetration, the knowledge about the whole system in many cases is distributed over a supplier-manufacturer-network. In this case, it is a promising approach, to build up a virtual prototype in collaboration of this network. By exchanging validated submodels across company borders, the quality of simulation results can be increased enormously and at the same time, the individual effort for building up and parameterizing a complete system can be reduced.

As there are different simulation tools in a company according to its specialization, one obvious possibility is to build up a complete system by using supplied submodels in a so called coupled simulation (also: co-simulation). Co-simulation offers the advantage that submodels can be modeled in specialized simulation tools and in an adequate level of detail. Also, it allows to use numerical solvers which are optimized for each simulation task and at the same time, the integration step size can be adapted to the required level of detail of a submodel (e.g. according to the required eigenfrequency) [1]. Against the background of the fact, that co-simulation has not been established as a tool for cross-company product development, yet, and taking its above mentioned potential into account, co-simulation shall be made accessible for the industry sector of mobile machines.

The Project GUSMA

GUSMA is the shortcut of the project “Coupled Simulation of Mobile Machines between different business partners for the virtualization of the product design” in German. It is funded by the German Federal Ministry of Education and Research (BMBF) and supervised by the Project Management Agency Karlsruhe (PTKA) at the Karlsruhe Institute of Technology (KIT), Campus North. The project started on 01.08.2008 and it ended on 31.12.2011. The objective of the project was to illustrate the applicability of the cross-company co-simulation of mobile machines.

Fig. 1



Platform concept in the project GUSMA

In order to use co-simulation as a tool for cross-company collaboration in product development process, the main focus in the project was put on the element of standardization. The standardization approach is based on three pillars: the idea of a platform, a standardized data interface and a standardized procedure. Also, the protection of know-how during model exchange was emphasized.

The idea of a platform

Starting point in the project was the idea of a platform on which a coupled simulation can be executed (**Figure 1**). The system, which is to be simulated, therefore has to be split up into submodels of different domains or submodels of different manufacturers/suppliers. Each submodel can be created in a domain-specific simulation tool and then it can be exported in a platform compatible format. By exporting the submodel and its corresponding conversion, the protection of know-how was realized. Ideally, except the protected submodel, also the corresponding solver should be exported as well. This way, each submodel can be executed independently.

As a basis of the platform, Mathwork's Matlab/Simulink was chosen. Being widely spread in industry and the large number of available interfaces from many commercial simulation tools contributed primarily to the decision. This shall allow an easy application of the GUSMA platform and it shall offer an opportunity especially for small and medium-sized enterprises to apply co-simulation across company borders in the development process.

Definition of a standardized data interface

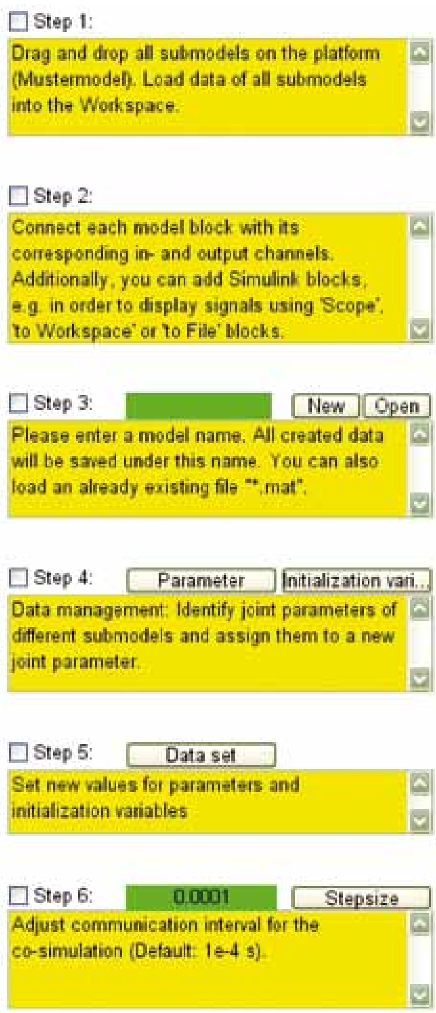
For the data exchange, the workspace of Matlab was determined as data storage. As a central element of Matlab, the workspace represents a reliable solution which guarantees especially version independency and which requires hardly any maintenance. All released simulation data – parameters and initialization variables – are written into the workspace during the submodel import and afterwards they are also read out from there. For the exchange of data, a parameter or an initialization variable has to contain the following information: the name and the value, the factor to the corresponding SI-unit, the unit itself and a so called 'marker'. This marker differentiates between the values 'p' and 'iv', which determine, whether there is a parameter or an initialization variable.

Introduction of a standardized procedure for building up a co-simulation

In order to ensure an efficient workflow for the build-up of a co-simulation, a standardized procedure was implemented via a graphical user interface (GUI). This procedure includes six steps in order to build up a fully functional co-simulation starting with the exported submodels [2]. **Figure 2** shows the GUI.

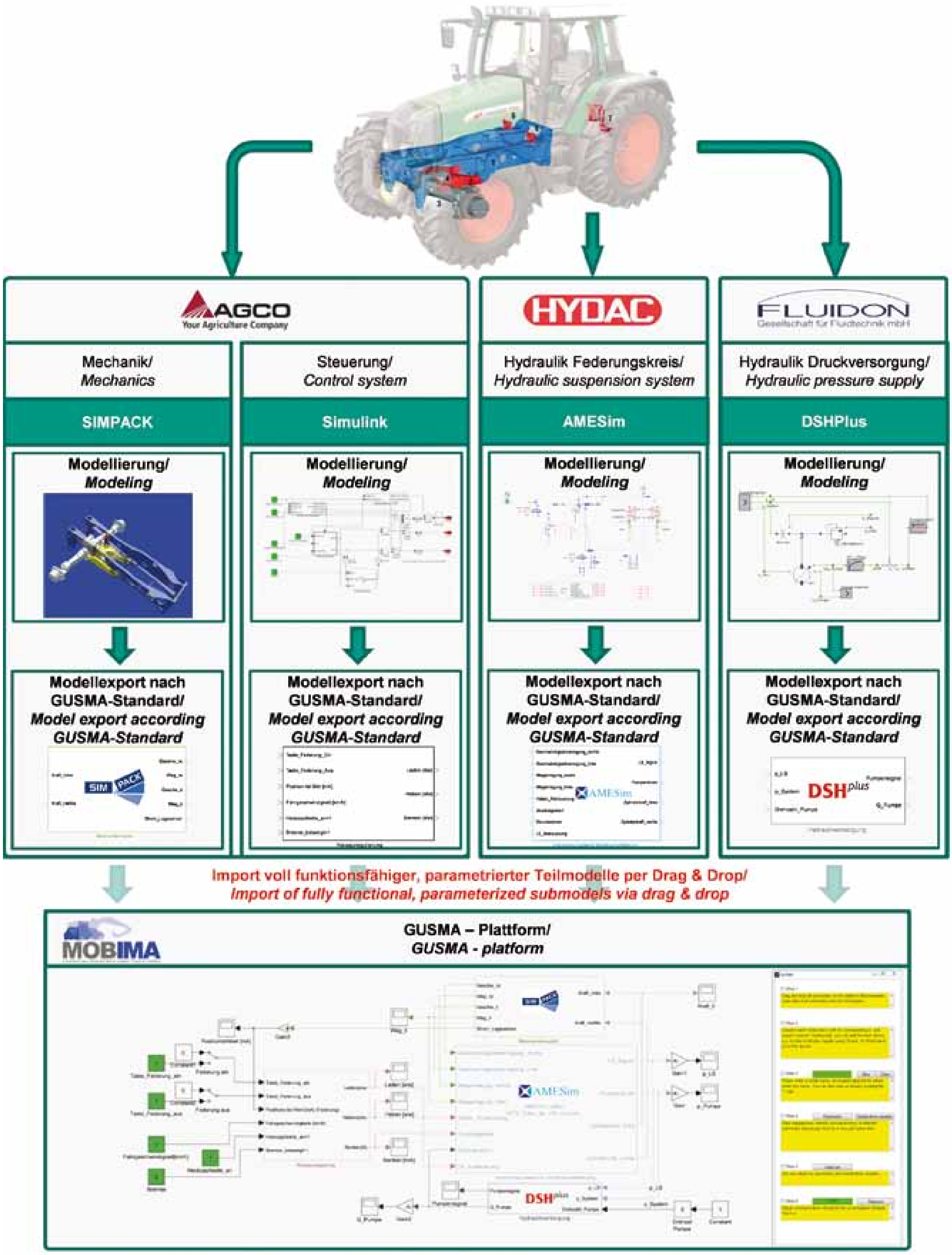
In the first modeling step, all submodels shall be drawn on the platform. The parameters of the submodels are imported automatically in the background. In the second step, the submodels shall be connected with each other according to their in- und output variables. Items from the Simulink library, such as visualization or storage options, can be added as well. In the third step, in case of a newly built up model, the user shall enter a filename for the released and accessible data. Alternatively,

Fig. 2



Standardized procedure for building up a co-simulation with a graphical user interface

Fig. 3



Cross-company system development at the example of a hydro-pneumatic front-axle suspension of a tractor earlier saved or different data sets can be loaded at this point as well. In the fourth step, the user is able to manage the parameters, which are accessible for him, by identifying and setting the joint parameters or initialization variables. Joint parameters or joint initialization variables are part of the accessible data, which appears in different submodels (e.g. the length of a cylinder or the preload pressure of various hydraulic nodes), and therefore shall be set unitarily in the complete system. The last two steps are designed to support the simulation process itself. In the fifth step, the possibility is given to change the value of modifiable or joint parameters. The sixth step allows to set the communication interval for the co-simulation. This interval defines the temporal step size, when submodels exchange data among each other.

After completing the above mentioned steps, the simulation can be executed using the start button on the Simulink platform.

Implementation of objectives

The project is realized in a consortium consisting of

- a research institution, the Chair of Mobile Machines, KIT,
- an OEM, AGCO GmbH/Fendt,
- a supplier, HYDAC SYSTEM GmbH and
- several software companies, Fluidon GmbH, LMS Deutschland GmbH and SIMPACK AG.

The cooperation of these project partners and their permanent exchange contributed to a continuous validation of the practical useability of achieved research progresses. The participation of the mentioned software companies ensured the feasibility of the standardized procedure, as well as the integration of necessary software functionalities.

Cross-company co-simulation of a tractor's front axle

The standardized procedure for the coupled simulation was validated at the example of a level controlled, hydro-pneumatic front axle suspension system of a tractor.

Concerning the system simulation, the hydro-pneumatic front axle suspension was divided up into submodels according to the actual division of labor between supplier and manufacturer and consequently, also according to the involved engineering domains, as to be seen in **Figure 3**. There was one model for the control system, one for the mechanical system and two for the hydraulic system. There were two hydraulic models, as the hydraulic pressure supply and the hydro-pneumatic suspension came from different suppliers. After defining the distribution of work packages, the corresponding submodels were modeled in the companies and were exported at the end according to the GUSMA standard. The simulation of the complete system was done at Mobima, which in this case took over the role of the vehicle manufacturer. There, every submodel was put together to the complete system according to the above mentioned steps and simulated.

Afterwards, the virtual prototype of the hydro-pneumatic front axle suspension system on the GUSMA platform was validated by practical tests on a test bench. The results were evaluated and were used for the optimization of the simulation model.

Conclusions

Co-simulation can be helpful to use in product development for the build-up and usage of virtual prototypes by modeling the system across department or company borders. Here, the know-how of a supplier can be integrated in the product lifecycle at an early stage of product development without disclosing the know-how itself.

In the joint project GUSMA, a possibility was created to use co-simulation as a tool for cross-company collaboration. This was mainly realized by the standardization of co-simulation. Therefore, a co-simulation platform was developed on the basis of Matlab/Simulink. This platform supports the user with a defined procedure building up a co-simulation and it integrates an easy handling of the data and the models of the complete system. The integrated protection of submodels, which also was elaborated in the project, underlines the given possibilities for the cross-company cooperation.

The software platform was validated at the example of a level controlled, hydro-pneumatic front axle suspension system of a tractor. This was accomplished not only with the virtual model upon the developed platform but also with practical tests on a test bench.

Using the GUSMA platform, submodels can be exchanged across department- and company borders. They can be used independently of the original modeling environment. This aspect opens up new possibilities in order to combine the expertise of vehicle manufacturers and suppliers in an early stage of the product development process. This way, the cross-company simulation can highly contribute to the optimization of time and costs in the development process.

The GUSMA standard will be published as a guideline of the VDMA (German Engineering Federation). The guideline is in process of implementation at the moment and will be available in the middle of the year 2012. Interested parties are welcome to contact the Chair of Mobile Machines.

Literatur

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Acknowledgements

The Chair of Mobile Machines would like to thank the BMBF and the PTKA for the cooperation and the financial support. Special thanks are due to all project partners for the successful collaboration.