First published in: Solutions for intelligent and sustainable farming. Düsseldorf : VDI-Verl., 2011. ISBN 978-3-18-092124-2. S. 123-128

Cross-company development of virtual mobile machines using a standardized co-simulation

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Abstract

The mobile machine industry is well-known for the development of complex mechatronic products. Additionally, low output volumes and a large number of product variants emphasize the requirement of a highly efficient product development process. In recent years, the virtualization of product design has turned out to be a key factor for reducing development time and costs. Especially for cross-company engineering, the development of virtual products by using a coupled simulation represents a promising approach. However, co-simulation has not been established as a common method on this market yet, there are still many challenges to take. In the project GUSMA, these challenges are accepted and an effective solution is developed.

Growing importance of collaboration in product development

The complexity of mobile machines has high demands on the product development process. Nowadays, not only vehicle efficiency but also the balanced adjustment of the vehicle's drive train and its working aggregates is enormously important. That's why an integrated perspective on mechanic and hydraulic actuators, as well as the control systems during the product development process of mobile machines is essential. Regarding the on-going electrification in this industry, such an approach gets even more significant.

Especially in an early stage of product development, the application of simulation tools has turned out to be a key factor in reducing development time and costs. This way, not only valuable information about a future product can be gained at an early point of the development process, but also potential risks can be identified.

An important difference can be seen in the procedure of modeling which has an influence on the possibilities on how companies can collaborate. Generally, it has to be differentiated between the number of modeling tools and the number of integrators in a simulation. Figure 1 gives an overview on this. For further information, please also see [1] and [2]

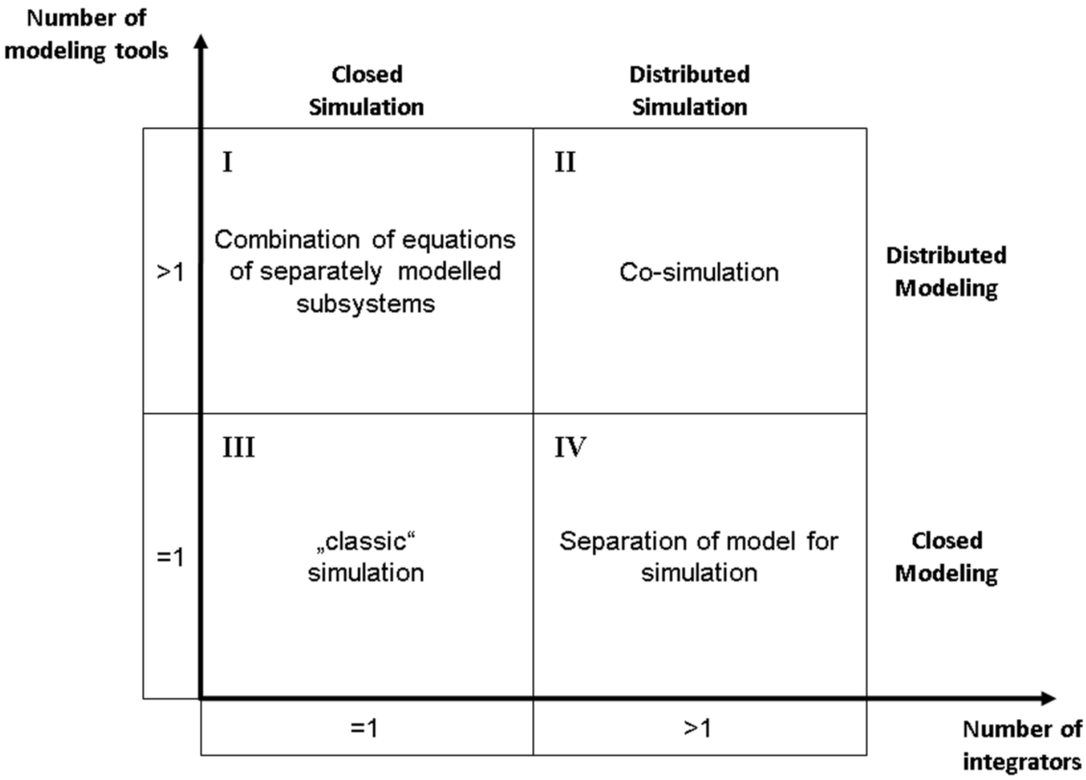

Fig. 1: Modeling variants (on the basis of [1])

For the modeling process of complete systems, two different possibilities have been established. For the first one, specialized programs have been enhanced to so-called “multi-domain-programs” by providing program libraries of different domains to the user. This corresponds to modeling variant III in figure 1. In this case, the advantage of the specialization for a domain is partly lost. The second possibility is to use a specialized program for every domain, where the corresponding subsystems or components are modeled, and couple them on a shared platform via a so called co-simulation, see also variant II in figure 1.

A coupled simulation provides the possibility to accelerate the engineering process by modeling the corresponding submodels simultaneously. It also has the potential to facilitate cooperation between different departments or even companies. This way, a co-simulation contributes to the optimization of the development process in terms of the Simultaneous Engineering method, as well as the approach of Collaborative Engineering.

Although many programs already provide interfaces for co-simulation, the interdisciplinary coupled simulation in the area of mobile machines however has not achieved complete acceptance so far.

Challenges for using a co-simulation

For using a coupled simulation as modeling variant, certain challenges have to be taken. A basic prerequisite for a co-simulation is the compatibility of submodels. Additionally, each submodel has to coincide with the demanded in- and output values of the system. This implies the settings of parameters and variables which are exchanged. As an example, the physical unit of the parameters or the factor to the corresponding SI unit shall be mentioned. This plays an important role especially for the model exchange between different business partners. Also, the protection of in-house know-how shall be mentioned.

During the simulation process, a temporal coordination between the coupled software programs is required. The communication effort as well as the often used fixed-step communication interval leads as a consequence mostly to a longer computing time as it would be the case for multi-domain-systems.

Co-simulation has not been established as a common method on the mobile machine market, yet. The above mentioned challenges have to be taken and the need should be fulfilled to make this modeling variant accessible for this industry.

The project GUSMA

From this idea, the project GUSMA emerged. GUSMA is a shortcut for “Coupled Simulation of Mobile Machines between different business partners for the virtualization of the product design” in German. It is a joint project 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 will end on 31.12.2011.

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
- three software companies, Fluidon GmbH, LMS Deutschland GmbH and SIMPACK AG.

The project results are validated at the example of a hydro-pneumatic front axle suspension of a tractor. The validation is performed not only with the virtual model upon the developed platform but also with practical tests on a test bench.

Standardization as a key solution

In order to make co-simulation accessible for the mobile machine industry, a standardized interface was introduced. Also, a standardized procedure for using a coupled simulation was implemented and so, its application shall be simplified and a broad distribution of the GUSMA standard shall be achieved.

Furthermore, a central element of the project is a platform on which a coupled simulation can be executed. The system, which is to be simulated, shall be divided up into subsystems of different domains and different manufacturers or suppliers respectively. Every submodel shall be created in its own domain-specific simulation program. Afterwards, it shall be exported in a platform-compatible format. By exporting the submodel and its respective conversion, the protection of know-how is realized. This way, a vehicle manufacturer shall be able to utilize validated submodels of suppliers – independently of which software environment the supplier uses. It benefits from the supplier’s expert knowledge without disclosing its know-how. Thus, a great part of the engineering process can be completed in simulation. The supplier on the other side enhances its competitive position by providing hardware and simulation models.

For the platform the software tool Matlab/Simulink was chosen. Being widely spreaded in this industry on the one hand and offering a graphical user interface (GUI) with visualization tools and possibilities of data handling on the other hand contributed to this decision. This way, an easy application of the GUSMA platform is ensured.

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

The GUSMA Platform

On the GUSMA platform a six-step-procedure is designed for the coupled simulation. If all the submodels of a system support the GUSMA standard, user can accomplish the co-simulation easily after six steps.

In order to simplify the work for the user and to support him along his working progress a graphical user interface was integrated on the platform. Figure 2 shows that GUI. Once the platform is opened, the GUSMA GUI will show up beside the main window. The six steps are listed on the GUI. Before each step, there is a check box, which has to be marked after each step. This way, the user is led through the build-up process of the co-simulation.

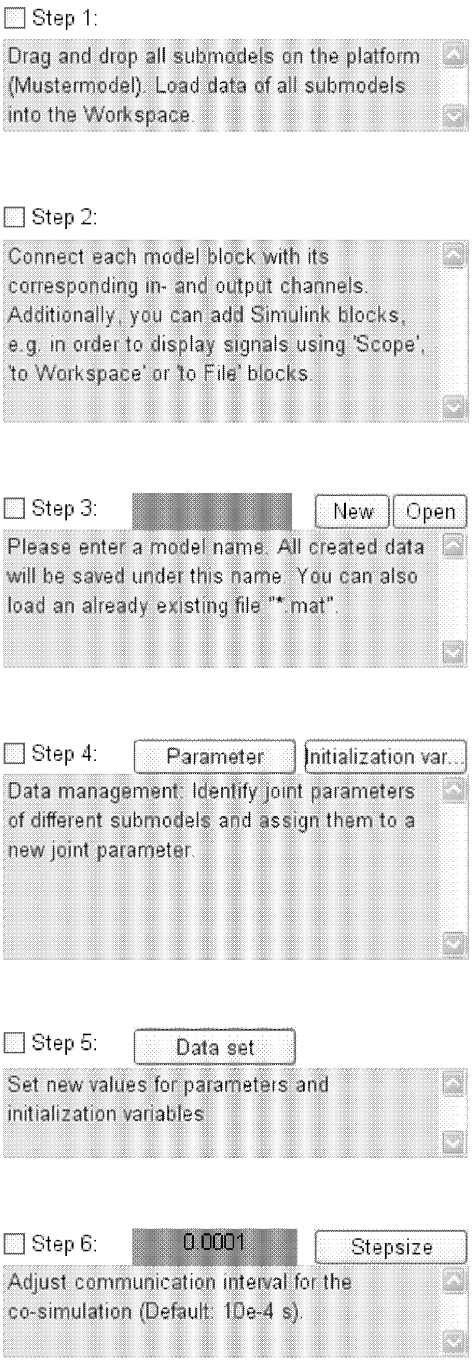

Fig. 2: GUI for user guidance

As it is known, each submodel of the complete system has a large number of parameters. In project GUSMA, these parameters are allocated in three groups – protected, modifiable and joint parameters. Protected parameters are visible only for the model creator and contain the know-how of the product. On the contrary, modifiable parameters can be viewed and changed by everybody. Joint parameters are the parameters, which have the same physical meaning and are included by different models.

In the first step, the user shall drag all the sub-models upon the GUSMA platform. In addition to this, the modifiable parameters of the sub-models will be automatically imported in the background.

In the second step, the user shall connect all the sub-models according to their in- and outputs. Items from the Simulink library can be added as well, for example the ‘scope’ block for visualization, ‘to workspace’ block for the storage of parameters.

In the third step, the user shall give a filename. The data which will be generated during building up the complete model will be saved under this filename. Alternatively, an already existing data set can also be loaded at this point.

In the fourth step, the parameters, which were imported in the first step are here separated into two groups. The first one, ‘parameter’, stands for the parameters, which will not be changed during the simulation, e.g. the geometrical values. The second one, ‘initialization parameter’ stands for the state variables, which are usually set up before simulation as start values. The user can manage these modifiable parameters and set them into different joint parameters, then in next step modify the parameters of same physical meaning unitarily.

In the fifth step, parameters can be changed to optimize the complete model and the different data set can be saved for the further use. Thus, the system optimization is ready to carry out. In the sixth step, the user needs not to set the communication interval of every model unitarily from the platform. For more information concerning the GUSMA standard, please also see [3].

Summary

In order to make the co-simulation available as a modeling variant between different business partners in the mobile machine industry, the joint project GUSMA was initiated. A simulation platform was developed based on Matlab/Simulink. The application of a coupled simulation using the elaborated standardized procedure shall facilitate the design of a virtual prototype. Partial models of different simulation tools can be easily integrated on the platform and can be connected according to their input and output variables. A centralized data and parameter administration was achieved by implementing a standardized interface.

The open concept of the GUSMA platform and the standardized co-simulation shall enable especially small and medium-sized companies to collaborate with each other and to increase their efficiency in the engineering process.

For the validation of the platform, a hydro-pneumatic front axle suspension of a tractor is used. The analysis of simulation and experiments led to valuable information about the necessary level of detail of a simulation model. A guideline for the level of detail shall be implemented.

The authors would like to thank the Federal Ministry of Education and Research (BMBF) as well as the Project Management Agency Karlsruhe (PTKA) for cooperation and financial support of the project GUSMA. Special thanks are also valid for the companies Agco GmbH, Hydac System GmbH and the software companies Fluidon GmbH, LMS Deutschland GmbH and Simpack AG, who are involved in the project.

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