Cross-Company System Simulation using the GUSMA-Standard for Co-Simulation

The industry of mobile machines is well known for the development of highly innovative and complex products. They are affected by all mechatronic disciplines, all of which can be found in one system. Along with the trend to intelligent and adaptive systems, automation is becoming more important on all system levels. This leads to an even higher interdependence between the specific mechatronic disciplines. Co-operation between in-house engineers and suppliers puts further emphasis on a highly efficient product development process. One promising approach is to establish close OEM-supplier-networks by using cross-company virtual prototypes. For this reason, a coupled simulation in a cross-company development process was created in the joint project GUSMA.

INCREASING PRODUCT COMPLEXITY AS A CHALLENGE FOR PRODUCT DEVELOPMENT

The demand for efficient products and processes can be seen in every area of our industry. On-going system automation, and the establishment of mechatronic systems, which are defined by a harmonic interaction of different subsystems such as mechanics, hydraulics, electronics, control and so on, underline this fact. In the future, enabling technologies such as cyber-physical-systems will have a high relevance in the market, and they will contribute to the growing complexity of technical systems [1]. Companies have to face these challenges and come up with new and innovative solutions.

VIRTUAL PROTOTYPES AS A KEY SOLUTION

In order to deal with increasing complexity in product development, the application of simulation tools has turned out to be a key factor for reducing development time and costs. Especially in the field of complex mechatronic systems, the approach of using virtual products seems to be promising. In an early stage of the product development process, a virtual prototype can help to gain valuable information, to identify potential risks, and to initiate according optimization measures. To build up a virtual prototype, it is essential to gather all existing expert knowledge about the product which is to be developed, including its subsystems. Depending on the manufacturing capabilities of a company, not only in-house departments but also external suppliers need to be included in the initial stages.

As an example, the industry of mobile machines is mainly characterized by small and medium-sized enterprises (SME) which are strongly interconnected in networks of suppliers and vehicle manufacturers. The products integrate the latest powertrain technologies with reliable and robust working functions. A large variety in product volume, which in some cases is as low as one, imposes high demands on the development of these machines. In order to face the challenges of increasing complexity as mentioned above, the usage of virtual prototypes including the vehicle manufacturer and its suppliers in a cross-company network seems to be a promising approach.

As for the predominantly middle-sized companies of the mobile machine industry, this approach has yet to be established. The joint project GUSMA pursued this aim.

THE PROJECT GUSMA

This project was a joint research project initiated by the Chair of Mobile Machines (Mobima) at the Karlsruhe Institute of Technology (KIT) in 2008. It ended in 2011. GUSMA is an acronym in German which stands for "Coupled Simulation of Mobile Machines between different business partners for the virtualization of product design". The project was realized in a consortium consisting of a research institution (Mobima), a vehicle manufacturer (AGCO GmbH/Fendt), an application company (Hydac System GmbH) and three companies in the area of simulation software: Fluidon GmbH, LMS Deutschland GmbH, and SIMPACK AG.

As every company uses different simulation tools depending on its specialization, the technology of the coupled simulation was chosen as a basis in the project. Coupled simulation or co-simulation is the connection of at least two modeling tools by using at least two numerical integrators (solvers) at the same time, see Fig. 1. In this way, it is possible to model each sub-system in simulation software which is suitable for the specific tasks in a company and which is familiar to the in-house engineer as well.

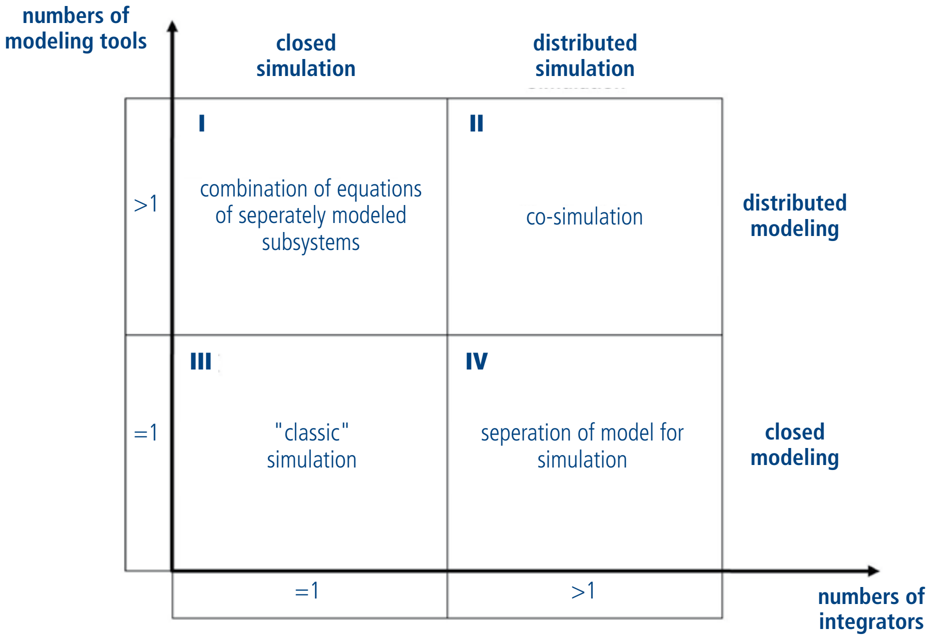

Fig. 1: Definition of co-simulation in context of using different modeling tools [1]

Additionally, a model can be solved with its optimized integrator, and an adequate integration step size — depending on which phenomenon and which frequencies are important. Last but not least, co-simulation provides the possibility of accelerating the engineering process by modeling the corresponding sub-models simultaneously — both in different departments or even different companies.

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The main objective of project GUSMA is to make co-simulation accessible as a tool for cross-company collaboration in the product development process. To ensure an easy application and build-up of a complete system using co-simulation, a key element in the project was the standardization of co-simulation. The standardization considers three aspects — the approach of using a central platform for the build-up of a complete system, a standard data interface and a standardized procedure for building up the system. Also, a focus was put on the protection of know-how for the exchange of simulation models.

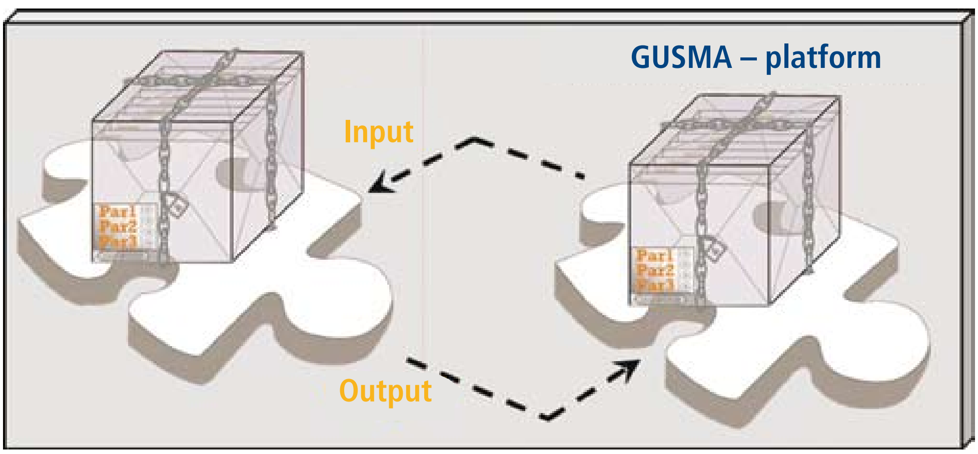

Fig. 2: Concept of the GUSMA-Platform

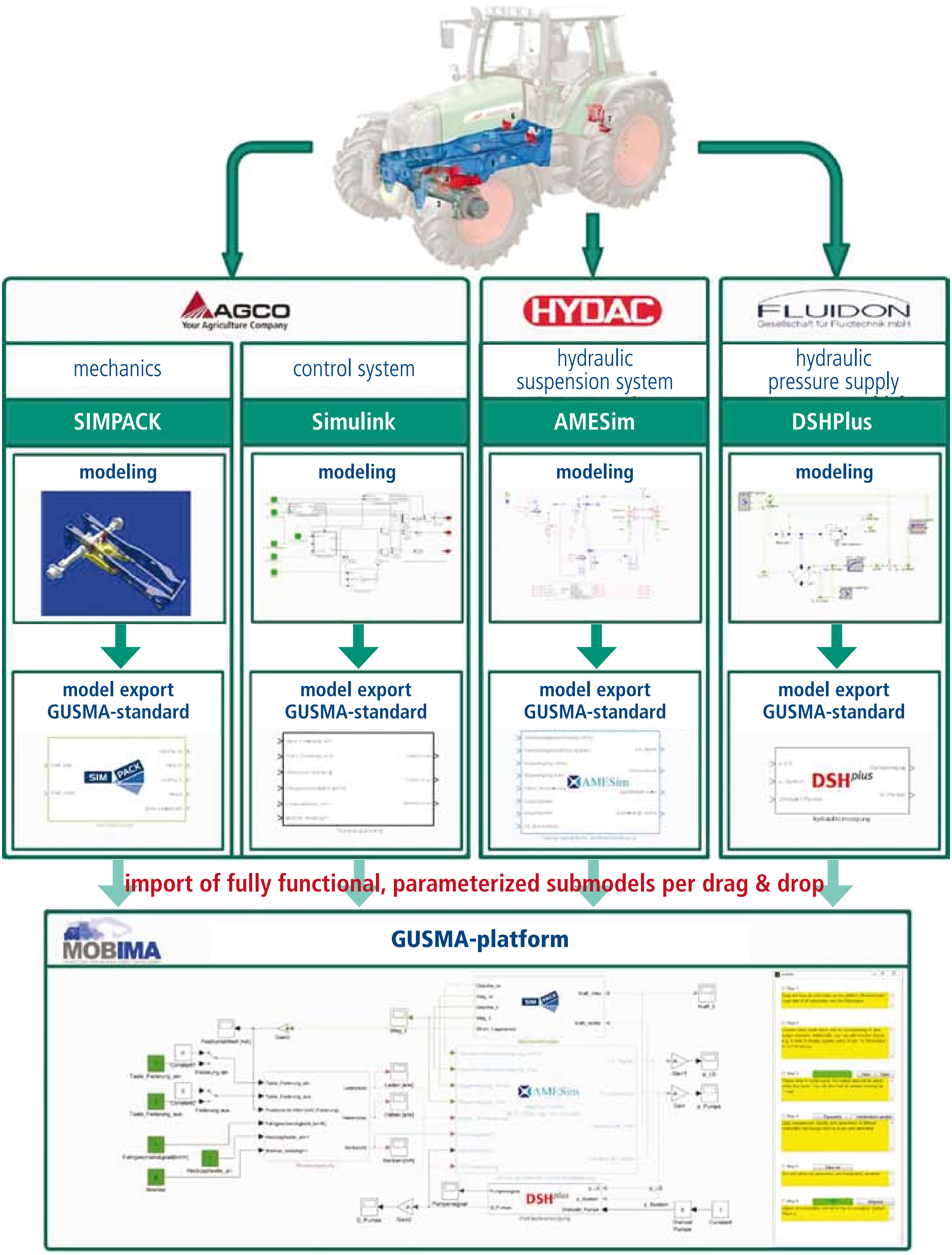

Fig. 3: Process of cross-company collaboration in project GUSMA

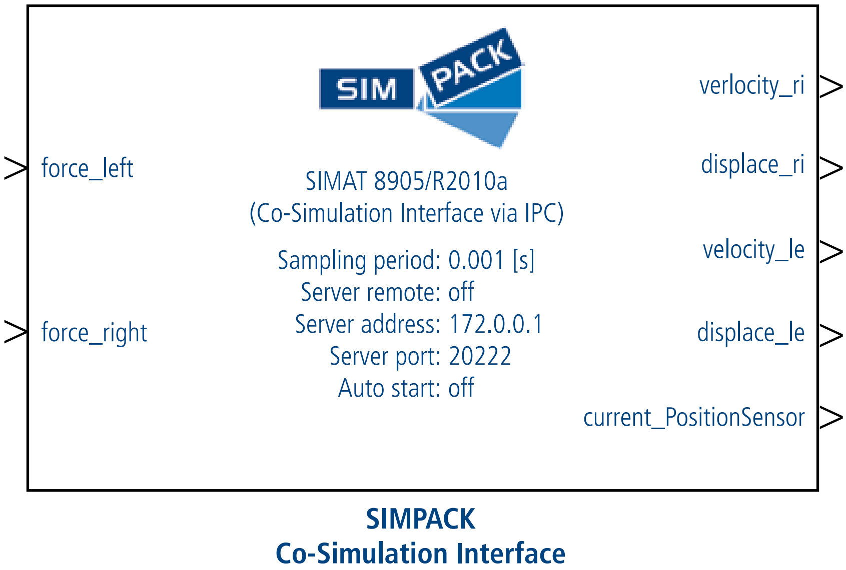

Fig. 4: Layout of the adapted SIMAT-Block according to GUSMA-requirements

THE IDEA OF A CENTRAL PLATFORM

A central element of the project incorporated the idea of a platform on which a coupled simulation can be executed. The system to be simulated can be divided up into subsystems of different domains and different manufacturers/suppliers, respectively. Every submodel can be created in its own domain-specific simulation program. Afterwards, it can be exported in a platform-compatible format. By exporting the submodel and its involved conversion, the protection of proprietary information is realized. Therefore, in the simulation program, where a submodel is created, the possibility to secure or hide data — such as parameters — has to be integrated. Ideally, apart from the protected submodels, the right solver can be exported on the platform so that every submodel can be executed independently. Fig. 2 shows this interrelation.

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The platform provides the possibility for each user to build up a complete model via a graphical user interface by linking the respective submodels. Additionally, administration of parameters and determination of initial values for the simulation is enabled. Finally, the feature of saving data is given on the platform.

As a basis for the platform, Mathwork's MATLAB® and Simulink® were chosen. On the one hand, MATLAB and Simulink are widely used in industry and, on the other hand, many commercial software tools already provide a co-simulation interface to Simulink. This way, the GUSMA Standard can be applied easily on the side of the software company as well as on the side of the customer. Also, it represents an opportunity, especially for small and medium-sized companies, to use co-simulation in the product development process beyond corporate borders.

STANDARDIZED DATA INTERFACE

In order to enable easy handling of all accessible simulation data — parameters and initialization variables — the workspace of MATLAB was chosen. As a central element of MATLAB, the workspace provides version independency as well as minimum maintenance.

While importing a submodel, all data is automatically written in the workspace. During a co-simulation, the GUSMA platform and all participating simulation programs exchange date via the workspace. The exchange data is written in a MATLAB structure array. Besides the name of the parameter or the initialization variable, the value, the unit, the factor to the corresponding SI-unit and a marker is transferred. The latter determines if the exchanged data is a parameter or an initialization variable.

REFERENCE APPLICATION AND CROSS-COMPANY COLLABORATION USING THE GUSMA-PLATFORM

A tractor's hydro-pneumatic front axle-suspension with level-control was used as a reference application to demonstrate the functionality of cross-company development with the GUSMA platform. Fig. 3 shows the process of this project.

After analyzing the system and defining the exchange variables in the project team, the In-house development of the simulation models began. Also, individual validation of the models was part of the project. The hydro-pneumatic front-axle suspension was split up into four submodels. A mechanical model, which was created in SIMPACK, and a control model of the level-control, modeled in Simulink, was created by AGCO/Fendt. In the project, two hydraulic models were used — one for the hydraulic suspension system and one for hydraulic pressure supply. This way, the real situation of two different suppliers for hydraulic systems is reflected. The company HYDAC modeled the hydraulic suspension system using AMESim, and the company FLUIDON created the hydraulic pressure supply in DSHPlus. During project GUSMA, all participating software partners implemented the requirements for the GUSMA-Standard in their software. In this way, all created submodels could be integrated on the platform proving its functionality. After each submodel had been modeled, the models were exported according to the GUSMA-Standard. In the project, a uniform layout of the exported model block (S-Function Block in Simulink) was added to the standard. Fig. 4 shows the layout of the adapted SIMPACK-Co-simulation interface block for MATLAB "SIMAT". As all the input and output variables are shown on the block automatically, the build-up of the complete system is facilitated.

The role of the OEM in the project was taken over by the research institution, Mobima, where the complete system was built up. The GUSMA-platform provides a standardized procedure for building up a fully functional co-simulation within six steps. A graphical user interface guides the user along these steps.

In the first modeling step, all submodels have to be drawn on the platform. The parameters of the submodels are imported automatically in the background. In GUSMA, parameters are distinguished between three groups — protected, modifiable and joint parameters. Protected parameters are only accessible for the actual creator of a submodel and they are not visible on the platform. This way, proprietary information of a company can be protected. Modifiable parameters can be viewed and changed on the platform (e.g., bezel size). Optimization of the entire system is enabled. Joint parameters are the parameters which are used by different submodels (e.g., cylinder length) and should be set and modified

unitarily. The same definitions apply to the so called initialization variables. These determine the start values of state variables, e.g., an initial pressure or position. In the second step, the submodels have to be connected with each other according to their in- and outputs. Items from the Simulink library, such as visualization or storage options, can be added as well.
In the third step, the user has to enter a filename. The data which is generated during the build-up of the complete model is saved under that filename. Here, the user is also able to load a data set which was saved earlier.
In the fourth step, the user is able to manage the parameters, which are visible for him, by identifying and setting the joint parameters — or joint initialization variables, respectively. In the fifth step, the possibility is given to change the value of all accessible data.
The sixth step allows setting the communication interval for the co-simulation. This interval defines the temporal step size when submodels exchange data among each other.

"...all created sub-models could be integrated on the platform proving its functionality."

After completing the above-mentioned steps, the simulation can be executed using the start button on the Simulink platform.
The complete system model of the front-axle suspension was validated afterwards with experiments on a test-bench.

CONCLUSION

The application of virtual prototypes offers great potential for time and cost reduction in product development processes. Especially in the industry of small and medium-sized enterprises, such as the mobile machine industry, the approach of using a coupled simulation for the representation and validation of complete systems in cross-company collaboration is very promising. In order to make the co-simulation available as a modeling variant between different business partners, the joint project GUSMA was initiated. A simulation platform was developed which integrates a standard for co-simulation and ensures intuitive handling. In this way, the platform can facilitate the application of a co-simulation and support the engineering process between different business partners.

A hydro-pneumatic front axle suspension of a tractor was used for validating the platform. This was executed not only with the virtual model upon the developed platform but also with practical tests on a test bench.
The software partners who participated in the project here already integrated the requirements for the co-simulation standard in their modeling tools. The GUSMA-Standard will be published as a guideline of the German Engineering Federation (VDMA). Interested parties are welcome to contact the Chair of Mobile Machines (Mobima) or visit the homepage (www.gusma.de).

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