Design of Adaptive Mechatronic Systems Using a Functional Digital Mock-up Approach

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In industrial product development, adaptive mechatronic systems play a rapidly increasing role. Historically, mechatronic systems are characterized by a coupling of the physical domains software engineering, mechanical engineering, and electronic engineering. But nowadays, also hydraulic, pneumatic and thermal subsystems have to be taken into account. Such heterogeneous systems provide a large variety of interactions between their subsystems. Hence, a holistic approach to modelling and simulation would be desirable when dealing with development of such systems. In the case of existence of adaptive components, the challenge becomes much more complex. Now, one has not only to deal with different physical domains but also with variable model structures. Figure 1 shows an example of a window regulator (left) and a driving motor (right) belonging to it. Because of environmental influences, functional restrictions or disorders may occur. Hence, it is worth to consider an adaptive system to increase robustness of functionality (adaptive controller, additional drive, heating system etc.). This may illustrate that a holistic approach is essential for design of adaptive mechatronic systems.

![Figure 1: Window regulator as adaptive mechatronic system](image)

For integration of geometric product models, Digital Mock-up (DMU) has been established as an inherent part of virtual product development in industrial practice. However DMU and the associated software tools are nowadays mostly limited to the integration of geometry. Possibilities of a functional integration are missing. In order to put mechatronic products on a solid base in an early stage of the development process, an extension of DMU with functional aspects towards a Functional Digital Mock-up and the support of cooperation between different physical domains are imperative.

Functional Digital Mock-up (FDMU) is a combination of traditional DMU with behavioural simulation in mechatronics. Enhanced with functional aspects, considerably more insight in product properties can be achieved. To enable a FDMU-like approach, two main tasks have to be solved: Established simulation approaches of the areas of diverse physical domains (mechanics, electronics, thermodynamics, etc.) must interact. This implies to solve the task of simulator coupling. Furthermore, the simulation results must be visualized using the geometric models of mechanical parts (DMU) as well as using special techniques to show results of non-mechanical domains.
In the contribution, a methodology and a prototype of an FDMU framework is proposed. Geometric models as well as physical models are combined to so-called functional building blocks (FBBs). The interface of every FBB is prepared to be connected to other FBBs. According to enable a simulation of an adaptive mechatronic system, all relevant FBBs are combined to build the so-called FDMU simulation model (FSM). A simulator coupling algorithm controls the simulation processes of each FBB during simulation. Depending on FBB’s physical domain, appropriate simulators can be used for simulation. The FDMU framework provides wrappers for multi-physics, electronics, software, multi-body, and FEM simulation tools. The visualization enables user interactions, e.g., pushing buttons. This way, parameters can be changed before each simulation run. All simulators are controlled by a so-called master simulator. This device has to organize the data exchange between all FBBs as well as the interaction between simulation tools and the user interface (see Figure 2).

Both tasks are not easy to handle. A correct data exchange scenario between the FBBs requires both an appropriate subdivision of the complete mechatronic system using causal signals between the subsystems as well as a sophisticated algorithm to control the sequence of starting/recalling the different simulators. Furthermore, the user interface has to deal with 3D visualisation of the mechanical part as well as various input/output streams for user-defined input parameters (model parameters can be controlled e.g. via sliders) and simple output visualisations (e.g. 2D plots). For this purpose, the ifX scene graph viewer software [4] is used in FDMU framework. This tool is a flexible and extendable framework for the interactive visualization of simulation data. Similar to integrating simulation tools, any 2D or 3D viewer tool can be plugged in using such wrappers.

The proposed FDMU approach is suitable for development of adaptive mechatronic systems since every adaptive part is appropriately included in an FBB and optionally switched on or off during simulation time.

References

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