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Standardized Classification and Interfaces of complex Behaviour Models in Virtual Commissioning

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Abstract

Today's increasing use of Virtual Commissioning during the development process of automated manufacturing plants paired with the increasing request towards better control quality leads to the need of improved virtual plants with more effortless set ups. The common techniques of simulating the plant within Virtual Commissioning do no longer fulfil these needs, new approaches have to be developed. This paper examines ways to standardize Functional Mock-Up Unit based behaviour models of mechatronic components of such automated manufacturing plants. It is argued how such components can be classified to reach a distinction between different types to be able to develop standardized interfaces for every type. Therefore a standardized framework of how these interfaces can look like is proposed. Based on this framework as well as the classification of the components two examples, a pneumatic valve cylinder combination and an industrial robot are exemplarily implemented. Besides the standard interfaces to the control program and the visualisation of the simulation a special effort to implement energetically considerations were made. Therefore the presented work shows a way of how to standardize the interfaces of behaviour models of different classes of mechatronic components while increasing the quality of these behaviour models for more complex and accurate behaviour simulation of production plants for Virtual Commissioning as well as related applications.

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1. Introduction

Today's evermore trend towards individual products, higher assortments and shorter life-cycles is not only changing the product development process but also the development process of automated production. It has to be more flexible to handle the rising product portfolio which ideally has to be produced on one production plant. One result of this flexibilization is that the usage of mechatronic components combined with control software is continuously rising and ensuring a high flexibility of a plant. Thus mainly software and barely hardware has to be adjusted when new products are going to be produced using the same plant. This trend leads to the fact that the control software developer spends more time for developing, optimizing and testing the control programs.

Virtual **C**ommissioning (*VC*) provides the control software developer with an approach how to develop and test his software based on a virtual model of the production plant [1]. This way of developing control software involves several benefits including more robust, higher quality and better level of maturity of the control programs, earlier and faster ramp-up of plants due to improved programs, higher optimization capabilities since it is easier to elaborate the virtual plant and several more. Even though VC is at the moment about to become standard in the development process of automated production plants [2], the behaviour simulation for VC (extensive described in [3] and [4]) is still a topic of research. The next step in the vision of being able to obtain the behaviour of a component not only as specifications in hard copy but also as a digital behaviour model, first presented in [3] and comparable to the evolution from 2D paper drawings to the deployment of 3D CAD data years ago is presented in this work. Therefore the approach of **co**-**s**imulation (*CS*) based on the FMI-Standard [5] was taken into account. As described in [3], this method enables the deployment of behaviour models from component manufacturers for the behaviour simulation. The single models are then co-simulated to simulate the behaviour of the plant as shown in figure 6.

2. Former work and motivation for this Paper

In [3] and [4], the importance of behaviour models of components for VC is extensively discussed. Moreover, the contribution [3] gives explicit both views of modelling and using of behaviour models by component manufacturers and users of

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VC. Thereby, the challenge that a component manufacturer is facing in modelling and providing behaviour models is debated as well as a way of how he is able to share its behaviour models with its users.Another challenges for the manufacturers is to define interfaces (*in- & output variables*) of their behaviour models user independently.

Regarding users of VC, the contribution [3] distinguishes between common users, plant manufacturers and service providers of VC. Common users (*e.g. OEMs*) are the users that contract out the development of production plants by plant manufacturers. A plant manufacturer, for his part, uses VC to validate the control programs of production plants. Both may also assign a service provider to conduct VC for them. The behaviour models however strongly depend on common user standards that regulate how components have to look like and how to use them in a production plant.

In [3], a distinction between behaviour models created by component manufacturers, referred to as **M**anufacturer **B**ehaviour **M**odels (*MBM*), and common users, referred to as **U**ser **B**ehavior **M**odels (*UBM*) is made. Thereby, *MBMs* are based on know-how of the manufacturer, and are modelled user independently. Moreover, *UBMs* can contain one or more *MBMs* and additional functionalities. The reason of this interleaving of *MBMs* into *UBMs* is to create the possibility to adapt *MBMs* to the requirements and standards of the users of VC.

Currently, *UBMs* are only created by the user of VC without *MBMs*, as these do not exist. Initial thoughts about the definition of interfaces of MBMs are one of the main topics of this contribution. Furthermore, the aim of this paper is to develop and present the needed interfaces to use *MBMs* for various simulations. To demonstrate this, the usage of the **F**unctional **M**ock-up **I**nterface (*FMI*) standard and its corresponding models called **F**unctional **M**ock-up **U**nits (*FMU*) are considered.

As an extension of the preliminary work, various classification systems have to be analysed regarding the possibility to classified each *MBM*. With this classification, the interfaces (in- & outputs) of each class of component (e.g. cylinder) can be defined. Thereby, the component manufacturer can provide his components as *MBMs* with standardized in- and outputs independently to customers respectively users. From a users view, an exchange of a *MBM* into a *UBM* can be done quite automatically with the help of standardized interface definition. Consequently, the modelling time could be reduced. Based on this, the analysis of various classification systems is briefly described in this work. Furthermore, a necessary interfaces framework (in- & outputs) of *MBMs* is presented and two components from different classes are taken as an example.

3. Taxonomy of mechatronic components

Prior to be able to define standardized interfaces for behaviour models, it has to be spotted which kinds of behaviour models are conceivable within VC. To do so, two approaches have to be considered. On the one hand, the common used components within automotive production plants have to be identified (including the classification of these components) to ensure that all currently needed components are considered. On the other hand, classification methods available across different disciplines have to be observed to enable a standardized classification of the used components.

3.1. Existing internal structures and components in companies

Since VC is used for the validation of the common engineering process, the application of behaviour models is state of the art, like described before. At Daimler for example, VC is one part within the *integra* automation standardization framework. Therefore the automation specialists have done some standardization work and classified the particular models within a logical, applicable system. The main groups are divided up as follows: Conveyor technique, subsystems, process engineering, general functions and special functions.

3.2. Appropriate methods of classification

There are a lot of different methods and approaches available to reach a classification of different objects. These methods are basically independent from single structures already existing in companies. Common industrial standards as well as different academic proceedings across different disciplines are taken into account and are described in this section.

3.2.1. Product specifications standards

With the ongoing digitalisation of the industrial world, a various amount of product specifications standards, have been introduced and developed during the last 20 years. The main goal of such standards during their development was the usage of faster and easier handling within sales, marketing and administration departments. Nevertheless, this standards can also be used for technical purposes and their usage in this field rose during the last years. The most common systems are [6], [7], [8]: eCl@ss, ETIM, GPC, proficl@ss and UNSPSC.

After the identification of the most common product specifications standards on the market, they have to be assessed. Therefore the five categories internationality (how many languages are supported, how many national consortia are available, etc.), dissemination on the market (how common is the usage), appropriate scope (are all needed elements available), appropriate structure (is the structure good to use for the focused use case) and appropriate structural depth (is the structure deep enough for the focused use case) were taken into account.

The result of this exploration was that out of the considered product specification standards eCl@ss is the most appropriate for the needs to classify mechatronic components for standardized interfaces of behaviour models in VC.

3.2.2. Multivariate analysis

Multivariate analysis is a method of multivariate statistics which analyses objects considering not only one but multiple variables of the objects. Within the multivariate analysis, there are two main methods, structure-identifying as well as structure-verifying methods. Obviously only structure-identifying methods have to be taken into account to create a taxonomy for mechatronic components. However, many of such methods are existing, e.g. factor analysis, cluster analysis, neural networks, multidimensional scaling and correspondence analysis [9], [10].

The most appropriate methods to classify mechatronic components seem to be the so called clustering or cluster analysis and neural networks. The other mentioned methods are more common to visualize and classify complex variables and not objects.