

RESEARCH ON SIMPLIFIED MODELLING STRATEGY FOR VIRTUAL COMMISSIONING

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ABSTRACT

Virtual commissioning (VC) of manufacturing systems has been a research topic for more than a decade, but there are still problems in accomplishing a VC; especially in respect to the effort needed to build a simulation model. To date the design of simulation models requires a considerable effort from skilled experts in each enterprise which seeks to use VC. Small and medium-sized enterprises (SME) usually do not have those experts. This fact and the significant effort typically make VC unattractive to SMEs. To overcome this problem it is necessary to provide sufficiently detailed simulation models of manufacturing systems, in a more cost effective and accessible way. This paper proposes changes in the way simulation models are generated and presents new concepts for simplified and systematic design of manufacturing system models for VC based on standardised recipes formalising design of mechatronic component models from CAD data.

Keywords: CAD, manufacturing systems, simulation model building, virtual commissioning

1. INTRODUCTION

Nowadays in a global competition, manufacturing systems must enable cost effective and flexible production. The industrial environment is characterised by shortening of product life-cycles, increasing number of product variants and a requirement for rapid time-to-market, which leads to a progressively tightening timeframe for manufacturing system engineering and the need for better planning quality at the same time.

Manufacturing systems are composed of many off-the-shelf parts and some purpose-built parts or sub-systems, like storage, magazines, conveyors, handling and transportation systems, machining and assembling tools, robots, control and HMI systems. After the product and plant planning phase the following engineering of manufacturing systems includes the mostly sequentially executed phases: mechanical engineering, electrical engineering and automation engineering with programming of robots, PLCs and HMI (Fig. 1).

Hitherto, after completing engineering, procurement and assembly, the real commissioning is finally done, and the traditional way of testing using the real plant and the real control system is still common. Design problems and programming errors in significant quantities remain undetected before the first system start-up. As a consequence of this procedure time and money consuming corrective measures become necessary. Because of time pressure and the risk of damages only rudimental failure scenarios are tested at this stage and unidentified errors result in additional time delays and increased costs during the early production phases.

One way of overcoming this dilemma could be virtual commissioning conducted between completed engineering and assembly of production facilities. The intention of VC is to test manufacturing systems and associated control programs through simulation conducted before the real systems are realised.

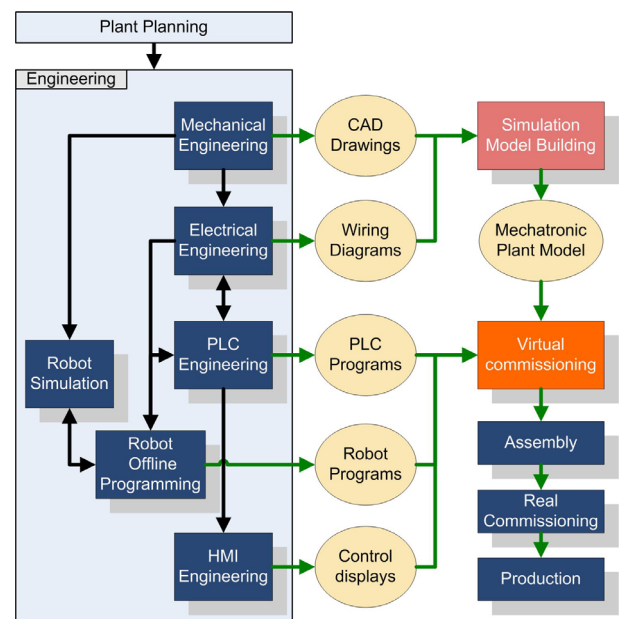


Figure 1: Engineering work-flow with VC

Conducting a VC requires a virtual manufacturing system. For this purpose a simulation model building

process combining data from different engineering tools is necessary. Currently this modelling is typically done using simulation tools promoted for VC.

An important goal of VC is the early validation of PLC code in conjunction with associated mechanical and electrical design, in order to reduce the considerable time delays during commissioning (Zäh & Wunsch 2005). Delays which are caused by the error-prone control code design. This and other advantages such as reduced real commissioning time and higher quality planning are meanwhile reported by many researchers, as reviewed in e.g. (Hoffmann et al. 2010, Jain et al. 2010). Many authors report the beneficial effects of VC (Zäh et al. 2006, Reinhart & Wunsch 2007, Rossmann et al. 2007) but indicated also the great effort needed for simulation model building (Park et al. 2006, Botaschanjan et al. 2009, Zäh et al. 2006, Neugebauer & Schob 2011). The review in (Hoffmann et al. 2010) showed a need for changes in the way simulation models are generated in order to reduce the effort as well as skills needed to build a virtual manufacturing system for VC.

2. DISTINCTION BETWEEN SIMULATION AND VIRTUAL COMMISSIONING

In spite of the mechatronic configuration of modern manufacturing systems, the development process is still focused on mechanical engineering and consequentially the simulation has concentrated primarily on design and mechanical engineering; where fit and specified behaviour of mechanical plant components must be ensured.

Simulation may be conducted by starting with plant design and material flow simulation, then continuing through all engineering phases to the realisation of a virtual manufacturing system with generic or approximate and parsimonious models. Sometimes the term VC is also used for these types of simulations, but a realistic VC is not possible until detailed engineering design has been completed and the real components have been identified.

For the sake of this discussion, the authors understand VC to be the simulation of comprehensively specified manufacturing systems using virtual simulation models and the original and unmodified control programs intended for deployment on the real system – as opposed to design verification by simulation in early engineering phases.

2.1. Separate simulation of mechanics and control – How both should work

To achieve a separate verification of mechanical design, a 3D simulation which is independent of the real control programs is sufficient to test the expected and specified mechanical behaviour (i.e. with no interaction with simulated or real controller).

In separately verifying control programs, a simple simulation at I/O level is often done (without interaction with realistically simulated mechanical elements, which would reflect the specified static and dynamic

behaviour of the manufacturing system e.g. with timing functions).

Such separate simulations are able to detect on one side mechanical resp. geometrical planning errors and on the other side deviations from the nominal behaviour instigated by control functions within the simulation tool.

2.2. Integrated simulation of mechanics and control – How the system will work

If the impact of control programs on the 3D mechanical behaviour of the manufacturing system is to be tested in detail and in an integrated manner, modelling and simulation of the complete functional chains is necessary. These chains would link control programs through sensors, actuators and drives onto the mechanical movements, and would include both, simulation of mechanical behaviour and of control programs. To achieve this, it is necessary to build a comprehensive mechatronic plant model (Fig.1), which should have its conceptual origin already modelled in CAD.

Such a VC is able to detect simultaneously errors in mechanical design, electrical design and control software. Typical errors have previously been identified (Neugebauer & Schob 2011). In contrast to real-world commissioning, testing of failure scenarios without endangering people or the risk of damages, is possible (Rossmann & Heinze 2010).

A VC requires a coupling between controller and the 3D plant simulation tool. This is possible through the following two configurations:

- HIL (hardware in the loop) using simulated plant and real PLC which is often realised using OPC (OLE for Process Control). The use of OPC together with simulation tools is critically analyzed in (Carlsson et al. 2012). A few tools support direct coupling via fieldbus or fieldbus emulation. Even the coupling of real robot controllers is possible within special configurations.

For the HIL configuration, the real PLC is required in advance, but VC is realisable before building the plant.

- SIL (software in the loop) using simulated plant and simulated PLCs. This is possible for different virtual robot controllers and is provided by several simulation tools. In addition to robot controllers, the plant simulation tool CIROS© (RIF 2012) provides the internal simulation of a Siemens S7 PLC or coupling to S7-PLCSIM via OPC.

The SIL configuration allows a complete VC without any hardware of the manufacturing system.

3. APPLICATION OF VC IN LARGE COMPANIES OR SME

3.1. Virtual Commissioning in large companies

In the context of the “Digital Factory” it is in principle possible to use the complex off-the-shelf factory planning suites of tools from the market-leading vendors (Delmia©, Siemens©) for a VC. These suites of tools support all phases of factory planning, but they usually require high investment costs, a high-level of training, high deployment penetration (whole departments), in-house secondment of consultants from the vendors for the implementation of custom-built functions and the laborious building of model libraries designed to the user’s specifications. Therefore, only large companies (e.g. in the automotive industry) selectively choose to conduct a VC using such suites of tools. Nevertheless the simulation models of complex manufacturing systems for VC are often not available in sufficient time to be justified for this purpose.

3.2. Virtual Commissioning in SME

The possibility and the advantages of VC are generally not well known in SMEs neither are the tools for VC, apart from perhaps, as part of the “Digital Factory” solutions. Consequently, there is only limited use of these solutions by SMEs, because they generally do not have the resources to start solving their problems with such “Digital Factory” suites of tools. (Drath et al. 2008b, Westkämper et al. 2003).

The start-up costs (licences, training etc.) are very high. These suites of tools are often too complex for SME to reasonably assimilate, and the change needed, from their previous practice using simpler and independent tools to these suites of tools would not generally be plausible. There is a lack of ‘easy to use’ engineering and simulation environments which could assist engineers in SMEs to set up and conduct VC. The time pressure during projects prohibits the simultaneous introduction of new methods and tools and would, in conjunction with the lack of skilled experts, inhibit uptake and the prerequisite building of simulation model libraries. If the number of newly built production lines is too small, there would be no return on investment in the training of personal and the modelling efforts for one project. Also, if the next project is dissimilar to the first, the modelling would often require again high efforts, as it will not allow the reuse of the already built library models. As a result of these facts,

the level of use of VC in SMEs is rare (Stern et al. 2010).

4. BUILDING SIMULATION MODELS FOR VC

Today, more than a dozen commercial simulation tools like ABB RobotStudio©, CIROS©, Delmia Automation©, InVision©, KUKASim© and VisualComponents© (3D-Create...), to name but a few, are available and applicable to VC.

In the context of this paper, the 3D plant simulation system CIROS© (RIF 2012) was chosen as an example. It was originally developed as robot simulation tool COSIMIR© at the University of Dortmund and allows HIL and SIL simulation as described in section 2.2. In addition, CIROS© provides features such as sensor and actuator simulation, collision detection, transport simulation for carrier based systems or AGVs, and also provides an XML model interface. Unfortunately, all such simulation tools require very difficult and time-consuming simulation model building.

The simulation model building procedure can be divided into two different modelling tasks:

1. (Low-level) component modelling
If not all required component models are available in the library of the simulation tool, (which is in general the case when starting with VC) remarkable efforts become necessary to build additional models from available CAD data.
2. (High-level) plant modelling
With CIROS© (and other comparable tools) the simulation model for the plant can be composed from component models using the simulation editor and provided that all required component models are already contained in the component model library.

By the means of high-level plant modelling it is relatively easy to set up a mechatronic plant model for VC, but even if this modelling of the virtual plant may be partially based on the plant CAD data provided by the plant designers: Especially the exact placement and the interconnection of the components is attendant on additional effort.

During the mechanical engineering of manufacturing systems CAD data of many off-the-shelf

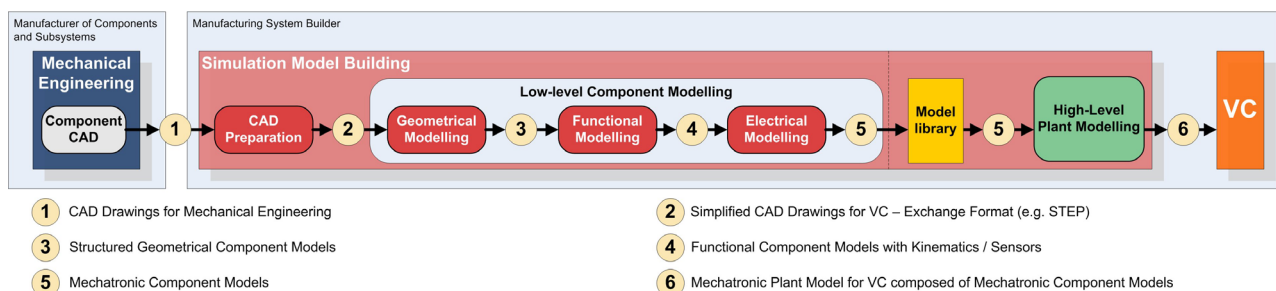


Figure 2: Workflow from CAD Drawings to Mechatronic Plant Model

components or subsystems (supplied by manufacturers) and of some purpose-built designs (in-house work) are composed to a 3D CAD plant model.

The primary source for the component models should be the manufacturer of components and subsystems. However, nowadays the component manufacturers provide 3D CAD data of the components (at best). This means that for all components not available in the component model library of the simulation tool a CAD preparation and low-level component modelling procedure (Fig. 2) must be carried out by the user which complicates the simulation model building for VC considerably and requires specific modelling expertise.

In this paper the low-level modelling procedure of components is critically reviewed and alternative approaches are proposed. The starting point is the 3D CAD model data for the components available either from the component manufacturers or the plant designers. In both cases (plant and component modelling) the 3D CAD model data must be pre-processed and transferred from the CAD system to the simulation system to allow efficient simulation of the geometry and the identification of model structures.

4.1. CAD Data Transfer

The CAD data transfer from CAD tools to simulation tools has other requirements than the data exchange between different CAD/CAM tools used in manufacturing engineering. Not necessary for VC are e.g. detail data like finish specification or tolerances, material data in contrast may make sense, e.g. for the simulation of an inductive sensor.

A big problem exists to date at the interface between the different CAD tools and simulation tools for VC (Fig. 2, ②). Even if functionally structured CAD models are available, the data interfaces allow in general only partial transfer (without kinematics) of this structure information.

In order to transfer kinematics additionally to geometry it is possible to use API (Application Programming Interface) functions for access to internal data of the CAD tool. Such a solution was demonstrated by (Neugebauer & Schob 2011). The disadvantage of this approach is the necessary programming and software maintenance of each combination of CAD tool and simulation tool.

From the authors point of view it is more promising to further develop suitable CAD exchange formats. There are a lot of established exchange formats with special advantages available (Friedewald et al. 2011, Fröhlich 2011), but none has established for exchange of kinematics.

In principle suitable formats for the exchange of geometry and kinematics are STEP (STandard for the EXchange of Product model data) and the Automation Markup Language - AutomationML (Drath et al. 2008a).

STEP supports kinematics since 1996 with its application protocol AP214, Part105 (Haenisch et al.

1996), but to date there is no industrial implementation in a tool. First approaches are presented by (Hedlind et al. 2011, Li et al. 2011).

AutomationML is a neutral, intermediate data format based on XML for automation data storage and exchange including component model data, not limited to geometry and kinematics.

The intention of AutomationML is the reduction of engineering efforts and quality improvement by interconnecting heterogeneous tools, which may become especially valuable when setting up VC with different tools and exchange of model data using AutomationML.

AutomationML combines several already existing standards respectively data formats.

- CAEX (IEC 62424) is used as top level format for the description of the topology and hierarchical structure of objects used in the manufacturing system (including necessary properties and relations between objects).
- COLLADA for describing the 3D geometry with mechanical interconnections and dependencies. The possibility of exchanging kinematics between different tools (e.g. 3D CAD and simulation tools for VC) is an important advantage compared to the exchange formats like STEP used today, where only exchange of geometry is implemented in tools.
- PLCOpen XML is used for the description of overall behaviour (including electrical and control information like I/O relations). Regarding the term “behaviour” it has to be distinguished between the internal behaviour of physical objects and the description of PLC code for controlling physical objects.

A first implementation of COLLADA import with kinematics into a simulation tool (ABB RobotStudio©) is presented in (Kuhlenkötter et al. 2010).

4.2. CAD Preparation

3D CAD data are the basis for the building of the simulation models, and CAD preparation is the first step for the design of mechatronic component models and thus important for VC. The 3D CAD data delivered from the manufacturers of components and subsystems or generated during plant design are not in general directly suitable for use in a VC simulation because most CAD models are geometrically too complex. This is why, a thorough model analysis and simplification of the CAD model data is usually necessary especially to reduce calculations. The goal is to reduce the number of details (geometrical elements) resulting in a reduced number of facets in the simulation model.

For example, the CAD data of aluminium profiles, used for many constructions within manufacturing systems (Fig. 6), must definitely not be used for simulation without simplification. Their complex

structures (Fig. 3) could extremely increase number of facets and extend calculation time.

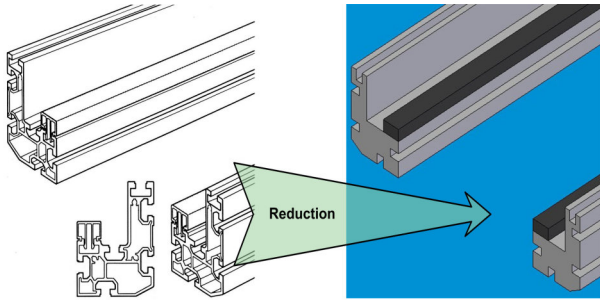


Figure 3: Example for simplified CAD from Bosch CTS© transport system

The complexity of CAD data is not the sole problem; the inner structure of a CAD models has often to be changed as well (to e.g. reduce calculation loading in the simulation and for better model handling inside simulation tools).

As consequence, the preparation of 3D CAD data for simulation has two requirements:

1. The CAD data complexity must be reduced to make real-time 3D rendering and visualisation possible. Even if the simulation tool is able to calculate independently the 3D visualisation, the visualisation should not differ that much. Deviation would hinder the human visual analysis of the operations in the virtual manufacturing system. This ability is simulation tool dependent; e.g. CIROS© provides configurable visualisation rates.
2. The model structure should consider actuating elements and sensors. The dependencies of objects moving together/separately or being stationary, and which geometrical objects are sensors, are all relevant and important.

A small example is shown in Fig. 4. The model structure has to consider a moving object (stopper) and two sensors.

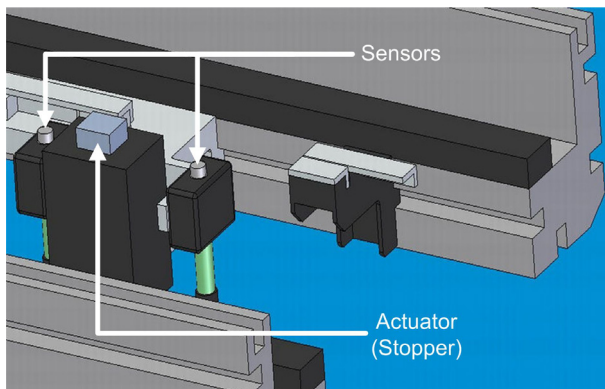


Figure 4: Stopper unit with sensors from Bosch CTS© transport system

If the CAD data provided are not appropriately structured especially with separation of moving parts, the data is not directly usable for the following low-level component modelling, nor is it possible to base a simulation on such model. In worst case, a CAD redesign may become necessary to provide in the geometry data the inner structures required for simulation.

In principle the preparation of CAD data can be done inside the simulation tool (see section 5.1, Fig. 5), which is often the case today, but then dispensable data has to be deleted and the model has to be restructured there with cumbersome detail work.

More efficient and overall faster would it be to prepare the 3D CAD data already inside CAD or simplification respectively conversion tools. In comparison with these tools the relevant simplification capabilities of simulation tools are limited and less controllable and the restructuring work is affiliated with more effort.

Modern CAD tools already provide several automated simplification features with adjustable filters to remove irrelevant geometrical features and irrelevant geometrical objects. If this functionality is not sufficient, it is possible to use specialised simplification respectively conversion tools such as: CADdoctor© (Elysium 2012), CADfix© (ITI-Transcendata 2012) or PolyTrans©/Nugraf© (Okino 2012).

Regarding the requirements mentioned above, the workflow for CAD model preparation for VC should comprise the following steps.

4.3. Simplification

Simplification can be done by removing features and removing parts.

- Feature Suppression: Removal of geometrical features irrelevant for simulation such as:
 - Holes, bosses, pockets, breakthroughs (not round), labels
 - Fillets, chamfers, roundings
 - Ribs, steps, slots
- Object Filtering: Removal of irrelevant geometrical objects like such as:
 - Hidden invisible parts
 - Small or other selected parts

The waiving of elaborate textures, respectively the definition as separate objects which can be deleted easily, is reasonable to allow further shortening of calculation time.

4.4. Component Structuring

Adjusting the CAD model inner structure is the crucial factor for CAD preparation. The model has necessarily to be separated to:

- static units
- moving units
- sensors

Up to now the building of assemblies in mechanical engineering is not done considering the functional interaction of parts, but rather aspects like common manufacturing are respected. Sometimes, that will lead to assemblies wherein static parts are mixed with moving parts. This was reported e.g. in (Hollander & Sappei 2011).

Assemblies created in mechanical engineering are often static, or all parts of an assembly move together. Converting such assemblies to single parts makes sense to minimise the calculation needs of simulation.

While working with CIROS© this practise has also proven advantageous for better handling of models during functional component modelling, because much less objects appear in the model editor.

Sensors have to be separate parts, regardless of belonging to a static unit or a moving unit.

The result of this preparation procedure will be a simplified component CAD model structured according to mechatronic considerations suitable for low-level component modelling.

After revising the CAD model, in respect to the feature objects and the structure to be adopted, conversion from exact model in a meshed surface model must then be done.

4.5. Tessellation/Meshing

The original CAD model is tessellated into a mesh of polygons, often done by triangulation to build a triangular mesh. Generally, it is essential to reduce the quantity of polygons for simulation purposes. Mesh simplification is a separate area of research for a long time and extensive studying originated a lot of techniques and algorithm. Basically, they can be divided into two groups (Kwak et al. 2010):

- Iterative coarsening of the complete mesh by removing polygons until a specified goal (e.g. number of polygons) is achieved
- Iterative refinement of a newly generated mesh (based on an initial approximation) by inserting polygons

The research in (Kuhlenkötter et al. 2010) shows the influence of quantity of facets and type of mesh (polygonal/triangular) on calculation time using ABB RobotStudio© as example. Unsurprisingly, the import duration and calculation time for collision detection ascends with quantity of facets, but the conducted experiments with a COLLADA importer offer big differences between polygonal meshes and triangular meshes. Ascending polygon quantity shows steeply rising import duration shortly exceeding one hour and leading to problems of insufficient RAM. In contrast, importing triangular meshes shows a gently inclined curve. Simulation tools for VC make use of collision detection between geometrical objects, and here as well triangular meshes show the advantage of significant shorter calculation time.

These findings allow the assumption to preferably use triangular meshed models for VC, and to limit the quantity of triangles as much as reasonable. Especially geometrical objects to be checked against each other with collision detection should contain as few triangles as possible.

CAD data providing different LOD (levels of detail) would be beneficial for simulation purpose. CIROS© for example supports different, changeable LOD.

5. RECIPES FOR LOW-LEVEL MODELLING

5.1. Conventional Low-Level Component Modelling from CAD Data (at the example CIROS©)

The starting point for this procedure is the 3D CAD model data for the components available either from the component manufacturers or the plant designers.

Building a low-level mechatronic component model in the conventional way means to describe the whole functional chain of the model, and can be divided into three stages: geometrical, functional and electrical modelling. The carrying out of this non-trivial procedure requires considerable modelling expertise and effort. Especially SMEs usually do not have the needed modelling experts.

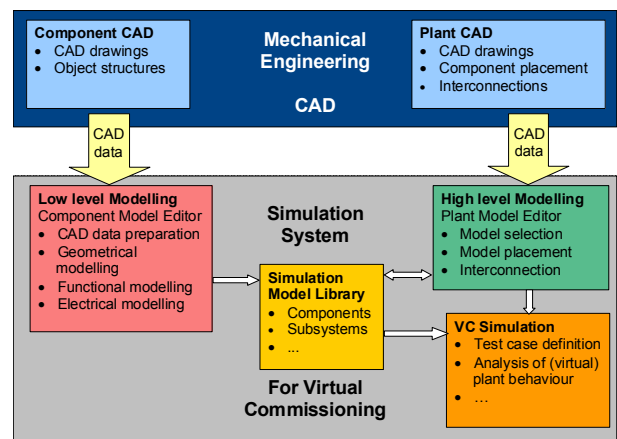


Figure 5: Simulation model generation: conventional recipe

5.1.1. Geometrical Modelling

Building mechatronic simulation models starts with the import and preparation of CAD drawings. For this purpose CIROS© currently provides import filters for STEP (AP203/214), STL, VRML and IGES. Simplification of exceedingly complex geometric data and restructuring would become necessary, if this had not been done in an external CAD preparation. CIROS© provides merging, aligning and optimisation of CAD data.

Adjusting the inner structure of these models considering static parts, actuating elements and sensors is the crucial step in creating the model. As mentioned above, the import of standard CAD data supplied from hardware vendors or in-house mechanical engineering often results in an unstructured or unsuitably structured

geometrical model. Having created appropriately structured geometrical models, these must be equipped with functions (functional modelling) and electrical inputs and outputs (electrical modelling).

5.1.2. Functional Modelling

As indicated in section 4.1 today it is not or only partially possible to transfer the inner structure of the 3D CAD model from the CAD to the simulation system, so it is necessary to manually equip the geometrical models with kinematics and when indicated with sensor functions.

CIROS© provides for this purpose several actuator functions such as translation, rotation, gripping and different types of sensor functions e.g. ultrasonic, optical, capacitive, inductive or light barrier. It is necessary to manually allocate actuator and sensor functions to the respective parts of the geometrical models. This results in the definition of integrated functional models such as push cylinder, rotational cylinder, turntable, sensor, gripper and so on. These models need parameterisation e.g. stroke and speed of cylinders or timing, measurement range, switch distance and hysteresis of sensors.

5.1.3. Electrical Modelling

For the final electrical modelling, it is necessary to manually assign electrical inputs and outputs to sensors and actuators in the functional models. CIROS© allows interactive, graphical editing of these connections. Later these I/Os will be linked to I/Os of control programs thus creating complete mechatronic simulation models.

5.2. Alternative Low-Level Component Modelling

To reduce the modelling effort for the user the following alternative approaches may be taken.

5.2.1. Component simulation model to be provided by manufacturer

For electrical CAE systems the component simulation models are generally provided by the component manufacturers. So in the long term a similar approach should be taken also for the components of manufacturing systems, i.e. the simulation models should be provided by the component manufacturers. This means that the manufacturers (and not the users) will have to handle the low-level modelling of their components. The motivation to undertake this effort can only be provided by the users, especially by the big users of simulation tools which may define the provision of simulation models as a general delivery condition in their commercial terms.

5.2.2. Low-level modelling during CAD design

The component designers have a clear view of the functional structure of the component. Today, however, only part of this general functional view is implemented in CAD models which represent predominantly CAD drawings perhaps with some limited object specifications. This means that the additional functional knowledge of the designer must be documented

separately or transferred from the designer to later users individually.

This is why the authors propose that:

- In future versions of CAD systems the functional and structure information of components must become an integral part of CAD design.
- The education of future designers should consider the structural organisation and inclusion of functional information (as required among others for the simulation models) in the CAD data. This should result in CAD model data with sufficient functional and structure to feed also simulation systems directly.
- In addition the CAD data interfaces must be empowered to transfer not only geometrical but also functional information (kinematics).

6. RECIPES FOR HIGH-LEVEL PLANT MODELLING

6.1. Conventional Recipe for High-Level Plant Modelling

The engineering of manufacturing plants is in general documented using CAD systems showing the placement of components in 3D and the interconnections of them. Simulation systems like CIROS© allow the aggregation and simulation of virtual manufacturing systems based on components in their internal library containing several mechatronic components or subsystems (for CIROS© e.g. from Festo© FMS such as conveyor systems (Fig. 6), assembly stations, handling stations and stocks, even robot models from different vendors (ABB©, FANUC©, KUKA©, Mitsubishi© etc.) have already been included. A similarly concept uses e.g. ABB RobotStudio© with so called “Smart Components”, but regarding robots it is limited to the use of ABB© products.

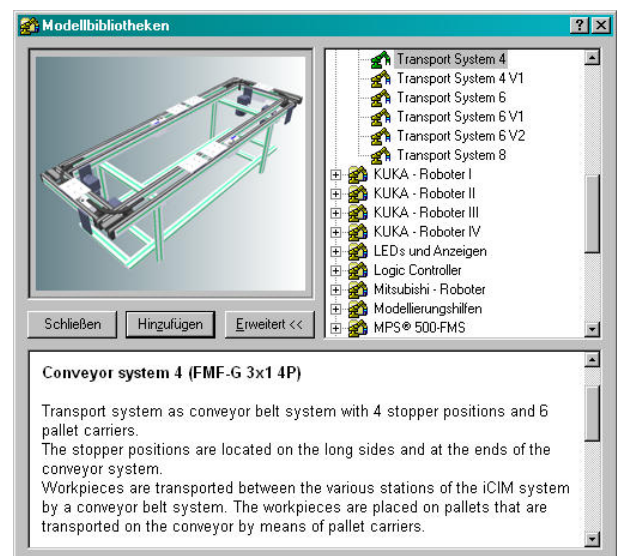


Figure 6: Example subsystem from CIROS© model library

These library models already contain the functional interaction of mechanical behaviours for actuators and sensors. If it is possible to compose the mechatronic plant model from such mechatronic components – high-level plant modelling - it is relatively easy to set up and conduct VC, because it will only require little additional effort when composing the plant model within the 3D editor and configuring I/O connections.

However, nowadays the geometrical information for the placement of the components and for their connections must be manually transferred from the CAD drawings provided by plant engineering.

6.2. Improved Recipe for High-Level Plant Modelling

In order to simplify high-level plant modelling for simulation the placement and interconnection information should be collected comprehensively already during CAD and transferred automatically to the simulation system such that the placement and interconnection of the components in the simulation model is done automatically (Fig. 7). This can be accomplished either by using improved data interfaces or by integration of CAD and simulation tool.

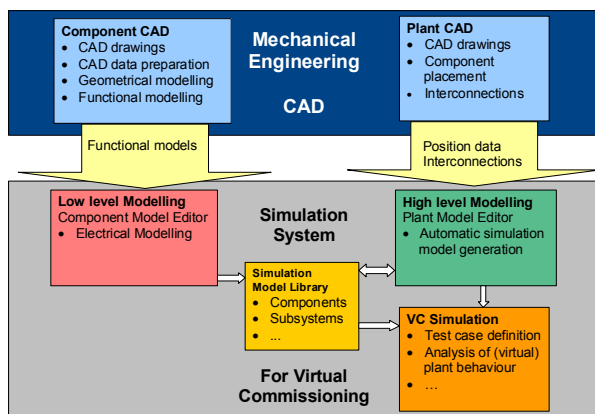


Figure 7: Simulation model generation: alternative recipe

The proposed approach of providing mechatronic models by the manufacturers of components or subsystems is supported by AutomationML.

7. SUMMARY AND FUTURE PROSPECTS

Currently, the simulation model building is carried out manually by the users of VC. It is not entirely possible until the engineering of manufacturing system is completely finished and all components are accurately specified. The necessary and laborious preparation of CAD models and low-level component modelling tends to result in serious time pressures. This may reach the point where delayed completion of the mechatronic plant models might result in their delivery after the real-world manufacturing system has been built.

An important first step towards simulation model building to be a task for control system engineers and commissioning engineers from SMEs would be the unimpeded transfer of CAD data to component

modelling. The data flow should facilitate and be directly applicable to low-level component modelling suitable for VC. Therefore, it is required that designers in CAD departments in components and subsystems manufacturing enterprises and designers from enterprises engineering, building and/or commissioning manufacturing systems consider the supply of such data. The supply of appropriate CAD data would greatly reduce the laborious CAD preparation always repeated at every use to a one-time activity. The low-level component modelling which remains necessary nowadays would be better facilitated and simplified. To achieve this goal there is a need for information to be gathered from designers creating CAD models, persuasion the manufacturers of components and subsystems to provide additional CAD data is recommended to facilitate component models for VC. In order to advance thinking in mechatronic units, CAD education in universities should address model transfer, reduction and reuse for low-level component modelling.

The future goal should be the availability of complete mechatronic models (like the models available today at end of low-level component modelling) provided by the manufacturers of components and subsystems. Already today the manufacturers should change over to provide 3D CAD data suitable for VC; this would be a good basis for future building of mechatronic models. Besides an appropriate exchange format like AutomationML, joint efforts for standardisation (e.g. model content) will be necessary for this purpose.

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