Title:

Workflows for the Exchange of Specialized CAx Data

Authors:
Lukas Weingartner, lukas.weingartner@jku.at, Johannes Kepler University, Linz
Alfred Sadlauer, alfred.sadlauer@jku.at, Johannes Kepler University, Linz
Peter Hehenberger, peter.hehenberger@jku.at, Johannes Kepler University, Linz
Stefan Boschert, stefan.boschert@siemens.com, Siemens Corporate Technology, Munich

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Introduction:

The exchange of CAx data, for instance between a construction and planning department and a calculation and simulation department, with standard tools is well established and documented. Methods for the transfer of CAD data to FEM simulations have long been available [1] and refined in recent years: examples range from (automatic) CAD geometry idealization [8] to methods for mesh model simplification by feature recognition [3]. There are promising approaches and solutions, such as a CAD/CAM/CNC toolchain using STEP-NC or ISO 14649 [11]. Well-defined procedures are used for such typical exchanges. However, as demonstrated by more recent publications, procedures that are seemingly standard can still be improved [5]. They can be part of well-integrated development environments, such as Siemens NX® and ANSYS® Workbench, or be realized using separate tools with clearly defined interfaces. These integrated environments and the interfaces for separate tools support frequently occurring interactions, and thus the corresponding procedures are also well established. However, tool support is often insufficient for novel applications and projects addressing individual aspects with low reusability, as is often the case in one-off developments. Machine and plant engineering is an area where one-off developments often occur. In addition, even when the necessary procedures are initially well established, changes within a project may require new functionalities of the product and the procedures.

Having analyzed the situation in one of the development projects of Siemens AG Logistics and Airport Solutions, we now demonstrate that a strict, standardized process is unable to address the individual needs of one-off developments. The processes implemented are re-invented for each project without consideration of the reusability of individual steps. In this paper, we address the research questions of how the processes for individual projects can be supported without a strict scheme and how process components of very specific processes can be reused in other projects.

One strategy to address these exchange issues in Systems Engineering is having a common language for representation, for example, the Systems Modeling Language (SysML) [2]. However, SysML lacks acceptance in industrial practice. In addition, although SysML theoretically allows representation of any engineering information necessary, specific details that are easily explained within a certain domain by domain-specific representation (e.g., technical drawings) become very complicated and almost unidentifiable in SysML. Another alternative for representation is provided by the standard data modeling language EXPRESS, which describes the information models of the STEP standard including geometry representation (e.g., STEP standard geometry/topology resource ISO 10303-42 [6]). A further approach uses a common data model [5]; even though they seem very promising for the future, data models are not yet sufficiently evolved for wide industrial application.

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Although there are widespread norms and extensive standards, it is well known that the exchange of data between CAx systems and simulation tools usually requires manual tasks and time-consuming customizations. As an additional solution, we present a method for unidirectional information exchange to create a simulation model based on existing design (CAD) data. We contend that this method simplifies individual process creation by means of a flexible guideline, and that it allows identification of process components in one-off projects, which in turn enables documentation and reuse in other projects. A case study demonstrates successful use of our method, which is now defined as a recommended approach for new projects at the company analyzed.

Main idea:

The data exchange situation between the construction department and the simulation department of Siemens AG Logistics and Airport Solutions was evaluated in a series of interviews, the generalized results of which are presented in Fig. 1. In the early design phases, the simulation department relies on project information to design initial concepts for a feasibility study. This project information is retrieved from the knowledge database, which includes the problem and task definitions, the requirement database and information about relevant standards and results from previous projects. Even though this knowledge database is depicted as centralized in Fig. 1, some information contributing to the concepts developed is distributed. An important example is knowledge in the form of experience of the simulation engineers. For concept generation, the simulation engineer must acquire the necessary information from all sources available. Model geometry is realized within the limited capabilities of the simulation software to the level of detail necessary for the desired generic functionality. A standard procedure is not necessary in this situation.

Once a concept is chosen for more detailed development, it must be designed for physical realization. The first step consists of creating virtual models comprising standard components, such as screws and nuts, and also specifically designed geometrical components. The CAD engineer again acquires the relevant information from the knowledge database in order to find a geometry that fulfills the geometrical requirements. A significant output of design using CAD software is the relevant information for manufacturing the components and assemblies, i.e. providing manufacturing knowledge [5]. The geometrical models are also used for further simulation. As previously mentioned, approaches that transfer CAD geometry to FEM have been known for a long time and are well established [1]. The transfer of geometrical models to software for the simulation of material flow, however, is not well established, perhaps because novel functionalities, novel improved software products and small lot sizes all complicate comprehensive standardization. As this exchange is not well established, the CAD engineer and the simulation engineer must communicate to determine the pre-processing steps required for including the geometry in the simulation software. Depending on the desired functionalities and the available interfaces, these preparatory steps can be performed in the CAD software, in intermediate pre-processing software, or in the simulation software. Communication between stakeholders can, of course, be complicated further by different areas of expertise of the engineers involved and the lack of guidelines and internal processes for cross-department cooperation.

In addition to knowledge and experience from the engineers involved, information for this pre-processing is, again, derived from the knowledge database. An illustrative example is a CAD model of a joint that primarily contains geometrical information. The engineer who creates a simulation model on the base of this CAD model, needs additional information like material data and boundary conditions to model the physical behavior. Here the functional use of the object plays the crucial role how the object is modeled (e.g., geometrical abstraction, physical behavior). A more specific example is the identification of a board beside a conveyor belt as a deflector. The CAD software does not naturally provide for the inclusion of such functional information, but realizing a conveyor system in the simulation software requires it. Defining a surface as a deflector is not supported by all types of geometry import interface (e.g., VRML) in the simulation software.

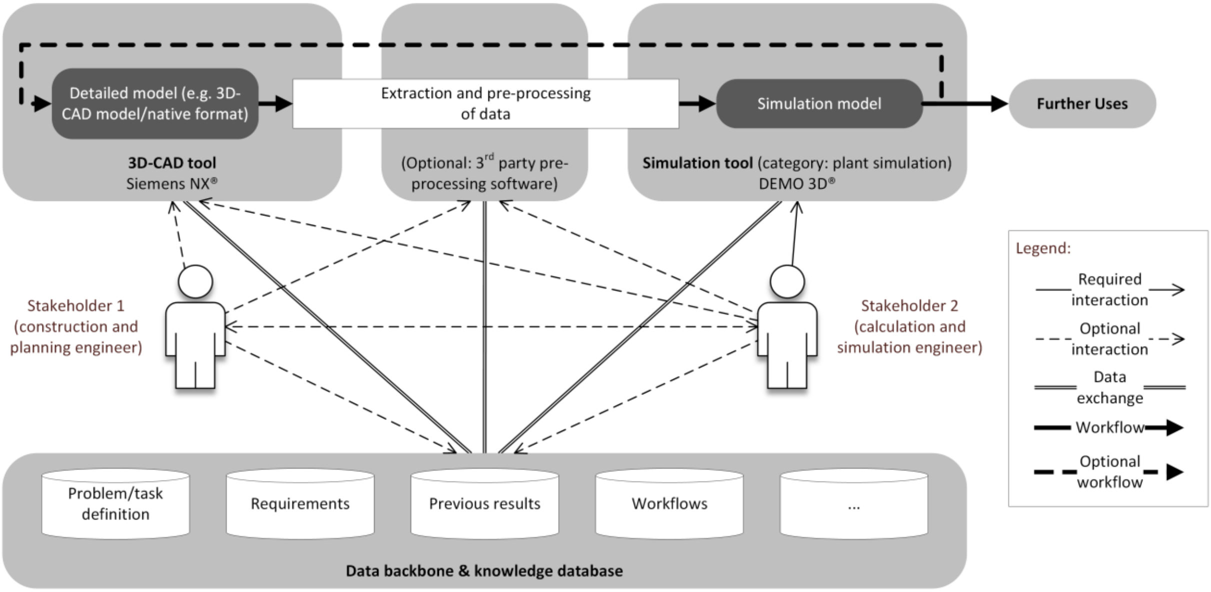

Fig. 1: Generic information exchange between CAD and simulation.

Thus, it is necessary to identify (i) the relevant properties that must be assigned to the geometry within the native CAD software, (ii) the interface for their successful transfer, (iii) necessary modifications outside of either the CAD or the simulation software and (iv) necessary modifications within the simulation software. Further, the modification tasks must be assigned to the stakeholders involved (CAD engineer, simulation engineer and potentially a 3rd party). In the case of large assemblies, the engineers must determine which components are to be included in, or omitted from, the simulation and which must be abstracted [7]. This process is comparable to the idealization of a CAD model for a finite-element method simulation [8]. For example, for a flow simulation, screws and nuts for component assembly can be omitted. Their inclusion would needlessly increase memory requirements and simulation runtime. Specific functionality allocation also requires abstraction of some elements to their core properties, such as weight or moment of inertia, omitting the overall geometrical information. For visualization purposes, such shapes can then be included using different (simpler) interfaces. Lee [7] presented some considerations that specifically address these issues.

Fig. 2 illustrates the generic process of information transfer from the CAD model to the simulation model. Once a detailed model of the geometry has been created, the properties that are relevant to the simulation can be identified and defined in the CAD software. A crucial prerequisite of such an analysis is knowledge about the goal of the simulation [4],[9]. The identification and definition step give rise to model modifications, after which the results are evaluated with regard to the requirements. Based on the results, the model is again modified and evaluated, and this iterative process continues until the requirements are met. Assigning selected and meaningful attributes within the CAD part models allows customizable and repeatable filtering of all necessary information. Once the pre-processed model exhibits all the relevant properties, it is prepared for, and then exported in, the appropriate interface format. Suitable interfaces must be selected depending on the individual task and on the support by the software tools used. The model is imported into the simulation software and subsequently prepared for the simulation. If some required properties could not be included within the CAD software, this must be communicated so they are added within the simulation software. The simulation model is then created. This is, again, an iterative process, this time with two cycles: The first focuses on the building of the simulation, and the second on achieving the desired results. Only when the model is fit for its purpose and can provide at least plausible results the process is finished. If significant problems arise within these cycles, it may become necessary to return to the start, i.e., the preparation of the geometrical model, or even to change the task. This process allows identification of specific steps necessary for specific properties (functionalities). Identification is followed by documentation of all the information necessary to create the expedient workflows, which can also have the form of modified software code. This documentation enables reuse of the specific process steps and workflows in cases where these specific properties (functionalities) are required again after major changes within the project, or in other projects.

The generic process illustrated in Fig. 2 was applied in a case study in which a conveyor system as part of a package-sorting plant was simulated. Part of this conveyor system were novel modules, such as Variomove® for faster unloading of bulk, along with new functionalities regarding user comfort and safety that had not been included in any previous simulation models. The novel simulations were applied for performance validation, geometry optimization, and to develop strategies and algorithms for bulk steam control and jam prevention. The inclusion of Variomove® was also further complicated by the large number of components included in this assembly. The goal was therefore to develop an efficient interface architecture considering established interfaces to increase the automation level, reduce error susceptibility and improve the quality of the simulation model. All applied workflows are intended to be stored for reuse in similar future tasks.

Although our approach proved successful in the case study addressing a new product, it also raised further issues. A crucial aspect is the handling of changes both in the CAD and in the simulation software. How can changes during development be successfully propagated between these two platforms without limiting the engineers in their tasks? How can the feedback from the simulation be communicated to the CAD engineer? Currently, this process at our project partner is relatively informal and could use improvement.

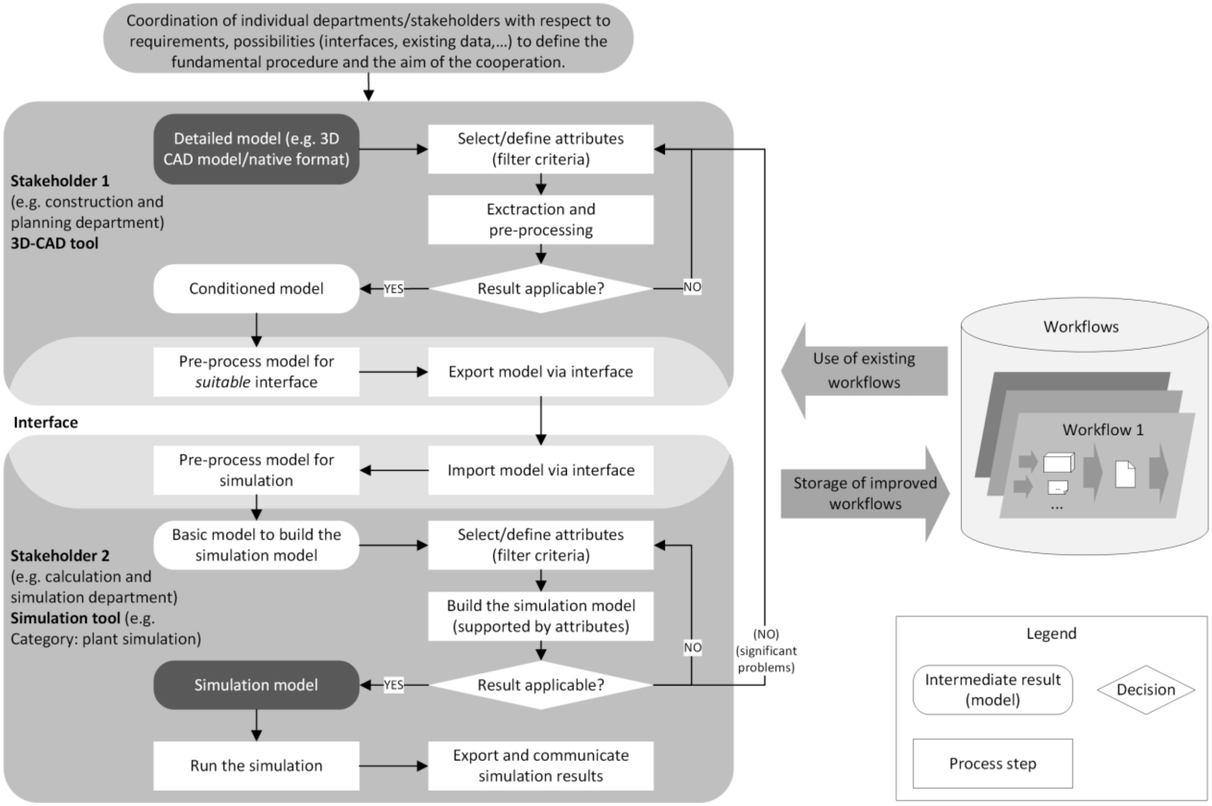

Fig. 2: Methodology for unidirectional information exchange between CAD and simulation tools (adapted from [10]).

Conclusion:

A situation analysis was performed at Siemens AG Logistics and Airport Solutions, and the CAx data exchange between CAD software and plant simulation software was evaluated. Based on this evaluation, we derived a method that allows non-established functionalities to be exchanged across the CAD and the plant simulation software. This approach allows documentation and reuse of steps and workflows in later projects. The process was successfully verified and validated in a case study addressing Variomove® integration. This case study provided further insights and future research topics concerning simulation feedback and the handling of changes in the course of a project [9]. Industrial adaptation and implementation of these findings is a further goal.

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