Title:
CAD-Automation in Automotive Development – Potentials, Limits and Challenges

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Keywords:
CAD-Automation, Knowledge-based Design, Generic Programming, Process Optimization

DOI: 10.14733/cadconfP.2020.56-60

Introduction:
The automotive industry is subject of continuous changes, which influence – among others – the vehicle development- and production processes. To maintain competitiveness, growing requirements on the development and production of cars have to be counteracted with appropriate measures. In the past decades, development process-related improvements have been influenced by systematic approaches, such as simultaneous engineering, frontloading and the introduction of corresponding computational development methods [3], [5]. The resulting higher flexibility of development processes led to a reduction of process times and thus to an increase of development efficiency, as well as the ability to react more quickly to changing product requirements. Computer-aided design (CAD) plays a central role in car development. It is applied throughout the entire development processes and interlinked with a number of computational and non-computational development disciplines. In this context, CAD-automation offers a high potential for further optimization of vehicle development and production. This extended abstract introduces different types of computational engineering methods in the automotive industry and their interactions with CAD processes. Subsequently, the levels of CAD-automation in automotive development are explained and discussed in view of their potentials, limits and challenges. Finally, an exemplary application of CAD-automation is elaborated for a specific development task in the automotive industry and evaluated regarding the benefits and potentials.

Computer-Aided Engineering in Automotive Development:
Virtual product development (VPD) includes the application of computer-aided methods and tools and plays an increasingly important role in the development of cars. Within virtual development processes, CAD plays a major role because the CAD models provide a comprehensive product description [4]. This includes geometrical definitions, materials, manufacturing-related data, structural information in case of assembly groups as well as a number of features and data of product definition. In this context, the CAD process plays an important role in product development [11]. Fig. 1 shows an overview of CAD and related computer-aided applications in a general automotive development process. The generic process is divided into five main phases: Definition Phase, Concept Phase, Pre-Development- and Series Development Phases as well as the Pre-Series and Start of Production (SOP). Throughout these development phases, a number of computational engineering disciplines come to use, e.g. requirements engineering (REQ ENG), computer-aided styling (CAS), digital mock-up (DMU), virtual- & augmented reality (VR/AR), computer-aided engineering (CAE) that includes a number of simulation tasks, computer-aided production engineering and -manufacturing (CAP & CAM), rapid prototyping (RP) as well as computer-aided quality engineering (CAQ). The large amount of different types, formats and versions of data occurring in automotive development processes is maintained by comprehensive product data management (PDM) platforms [3], [5], [6].

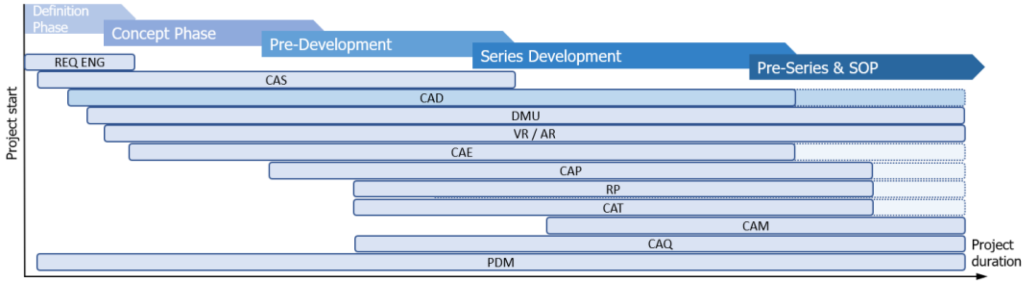

Fig. 1: CAD and related computer-aided processes in automotive development.

Fig. 2 shows the interaction of CAD and the mentioned computer-aided engineering processes. The CAD models deliver information about geometry, product features, design history as well as product structure-related information, e.g. in case of assembly groups. These data are provided to the adjacent engineering processes, which are parallel or subsequently performed. Depending on the specific engineering discipline, different types of information are derived from the native CAD models. In most cases, data exchange processes are conducted unidirectional from the CAD model to the corresponding engineering process. Nevertheless, in specific processes, bidirectional data exchange is established, e.g. in case of styling development (CAS), where styling geometry information is delivered by CAS and imported as rigid geometry models into the CAD environment to serve as boundary data for engineering-related development tasks [10]. Bidirectional exchange of detailed geometry data comes to use in case of multi-CAD environments, e.g. in the course of data exchange between different companies [9].

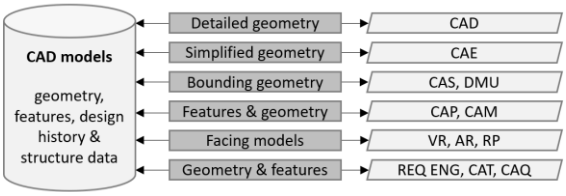

Fig. 2: CAD models as a central data basis for different computer-aided development processes.

<u>CAD-Automation:</u>
CAD-automation comprises creation, optimization and maintenance of CAD data, as well as the integration of CAD processes and other, parallel or subsequently performed processes (c.f. Fig. 1). In addition, CAD-automation involves data exchange between different engineering disciplines (c.f. Fig. 2) and the integration of automated procedures into the company- and project specific PDM systems [7]. Fig. 3 gives an overview of the different levels of CAD-automation, their complexity and indicates the corresponding creation- and maintenance effort. In addition, a number of techniques is aligned to the different levels. Modern CAD systems applied in the automotive industry offer feature-based and parametric methods for the development of CAD models. The so-called parametric-associative design methodology comprises semantics, algorithms and relations for an effective creation of the different types of CAD models and assembly groups [8]. In course of data exchange with neutral geometry data formats, e.g. IGES and STEP, rigid CAD models come to use. As a sub-discipline of knowledge-based engineering, knowledge-based CAD provides a systematic integration of knowledge into the design models by use of parametric-associative and feature-based design with extension of problem-specific solutions, e.g. in form of template models. In this way, it integrates specific knowledge about the product, development procedures and production-related information into the design process. Knowledge-based design uses automated routines (e.g. script-based geometry creation) and implements functions, rules and reactions into the CAD model. Template models include different types of algorithms and features to automated support the creation of specific models. Templates are often

based on the re-use of variable geometry models and library functionalities. In this way, knowledge-based design supports an increase of efficiency in the design process by re-use of design knowledge in combination with semi-automated geometry creation procedures and thus represents an important approach in view of CAD-automation.

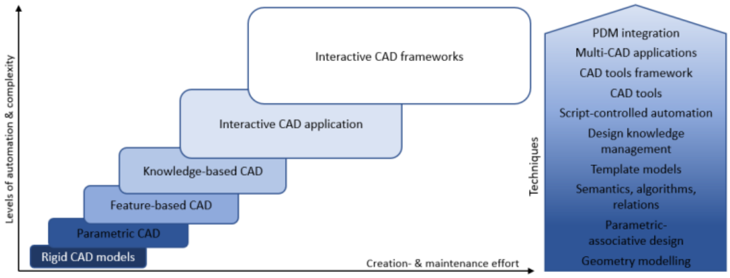

Fig. 3: Levels of CAD-automation and related design techniques.

Interactive CAD applications include functional software modules that are embedded into the CAD environment. They support complex and often recurrent performed engineering tasks effectively by an integration of geometry creation as well as different types of calculation and simulation procedures. Automated geometry creation is accomplished by a combination and automation of the CAD-internal functionalities. In case of complex simulation tasks or the involvement of large data structures into the computation procedures, different types of data sources are integrated, e.g. libraries, CAD-external simulation software [2]. In typical applications, users are guided by graphical user interfaces (GUI) as well as supporting functions. In this way, interactive CAD applications integrate methods of knowledge-based CAD, defined working- respectively computation sequences and user guidance. Typically, these tools are written in application-oriented program languages, e.g. Visual Basic for Applications (VBA), Visual Basic.NET (VB.NET). The creation of interactive CAD applications is similar to software development in general and consequently requires both know-how of the engineering tasks as well as software programming expertise. As part of superordinate software tool structures, interactive CAD frameworks integrate different types of engineering design-related applications. In many cases, the frameworks are defined according to the requirements of a specific company and provide sets of tools that effectively support development projects. In the automotive industry, both car manufacturer and (large) engineering- and system supplier have established their company-specific development tool landscape, which incorporate interactive CAD frameworks as one important section. In a multi-CAD approach, interactive CAD frameworks are able to integrate different CAD software environments in view of model exchange and collaborative development [9]. In addition, multi-domain applications are provided by docking to or integration of CAD-external simulation tools to the CAD-related engineering tasks. In this context, interactive CAD frameworks represent a comprehensive approach for creation, provision and maintenance of CAD-based engineering landscape. Due to the large extend and the close incorporation into company-specific development processes, PDM integration is mandatory. In addition, interactive tool frameworks require professional setup, development as well as maintenance and service.

Potentials, Limits and Challenges of CAD-Automation:

The number of automation processes in the field of CAD has increased significantly in recent years due to their high potential for process optimization. Especially in different types of development- and production processes, the use of CAD-automation can lead to a considerable added value, which is represented in savings of resources, costs and time. Furthermore, there is a high potential for the application of CAD-automation in engineering-related niche areas. This is of great interest especially if no off-the-shelf software tools are available on the market. CAD-automation packages can also help to increase quality of development- and production processes. This is enabled by the fact that the working principle of these tools is always based on their integrated functions, which enables parallel computing sequences. As shown in Fig. 3, the choice of automation levels in a specific case depends mainly on the expense- benefit ratio. In this context, the resources for creation and maintenance of the automation package must be taken into account for the expenses, which might lead to lower automation levels for specific applications. An example of how this can be achieved represents the multi-CAD approach in CAD-automation. If the majority of company-internal development processes are conducted in one CAD system, the effort required to create an automated multi-CAD-based environment must be compared with the potential benefits and is should be evaluated, if the use of standard conversion programs and neutral data formats is advantageous [5], [9]. A further limitation of CAD-automation can be attributed to the large CAD models commonly used in the automotive industry and the associated limitation due to the available computing performance. Automotive development involves a large number of different vehicle components (>10.000 parts) and the complexity of the CAD models is increased by associated information (e.g. parameters, material). Of particular interest is, how the high amount of data can be handled effectively.

Exemple Application of CAD-Automation:

The previously described potentials and limits concerning CAD-automation are demonstrated by an example of an automated tool (named "Joining Converter"), which is embedded in the automotive body development process. As described in the introduction, the development processes are divided into different main phases, in which different computer-aided systems are used. 3D-CAD modeling of the vehicle body components takes place in an appropriate CAD environment. The models include different types of information: geometry-related data (e.g. geometry and dimensions of metal sheets, center of gravity of the sheets) and joining technology-related metadata (e.g. type of joining technology, coordinates, joining technology-specific parameters, such as welding spot diameter, length of the screw). Both, geometry-related and joining technology-related data, are exchanged between the CAD source environment and several simulation environments (e.g. CAE, CAM) in the course of the development process. This exchange process manages both the required information for simulation tasks (e.g. fatigue strength, crash tests) and the feedback of simulation results to the CAD environment to be considered for design optimization.

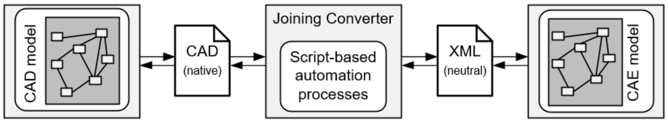

Fig. 4: Integration of the tool "Joining Converter" in the development process.

Since there are no uniform standards for the data exchange of joining technology elements [5] defined, joining technology source data can be available in a wide variety of data formats. On the one hand, this includes diverse native CAD data formats (e.g. CATIA, NX, Creo) as well as neutral data exchange formats (e.g. list-based (e.g. Excel), XML-based (e.g. xMCF [1])). As there are no off-the-shelf tools on the market for joining technology data exchange, a specific tool has been developed in the present work that offers an approach for data exchange between different sources and several computational engineering environments. The tool "Joining Converter", provides a generic approach to process the different types of data and to convert them into a uniform data exchange format by means of suitable script-based automation processes. Fig. 4 shows the integration of the tool into the development process, with the exchange of joining technology data from the source environment into the exemplary CAE target environment. The tool is designed in such a way that it either converts CAD-based joining technology data into a list-based or XML-based data format, or vice versa. In relation to the potentials and limits of CAD-automation, the tool supports both the data exchange process between different engineering environments and the entire development process of vehicle bodies. In addition to an increase in data quality, which is due to a lower error rate [5], this also leads to savings of resources, costs and time. Especially the cost and time saving potential resulting from the integration of the automation package is of crucial importance for competitiveness and supports an earlier market entry of automotive products. Due to the increasing data quality the tool "Joining Converter" also contributes to increased quality of development- and production processes. This in turn, leads to a lower failure rate of products. Referring to Fig. 3, this tool is based on a multi-CAD approach, which has been chosen due to the high frequency of application in car body development. Since this tool has a high flexibility regarding the input sources (i.e. support of a large number of native- and neutral data formats), the tool can be applied for a broad range of projects. The benefits justify the high efforts required to create, implement and maintain the automation package.

Conclusions:

Increasing complexity, integration levels and data volumes in computer-aided engineering applications as well as steadily rising time- and cost pressure call for effective tools and methods in automotive development. Due to the central role of CAD in automotive product and manufacturing development, the automation of both CAD-based engineering tasks and data exchange plays an important role for process optimization. In this way, CAD-automation is able to contribute to more efficient development processes and improves development quality at the same time – especially in case of complex and recurring working tasks. On the other hand, the creation, implementation and maintenance of automated CAD processes requires effort and specific know-how. In this context, automation activities have to be comprehensively planned, tailored and conducted under consideration of the specific boundary conditions and influencing factors. Key for successful implementation includes a clear understanding of the working tasks to be automated, a well-balanced benefit-cost analysis and the development of suitable solutions according to the actual requirements. At the end, CAD-automation has a great potential to support the creativity and productivity of the involved development engineers and to optimize automotive development effectively.

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