ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

A CONTRIBUTION TO ADVANCED KNOWLEDGE-BASED DESIGN IN THE DEVELOPMENT OF COMPLEX MECHANICAL PRODUCTS

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ABSTRACT

Management of product complexity under consideration of parallel performed working tasks in virtual development establishes as an important challenge that has to be considered to ensure efficient product development processes. The main goal is to develop a virtual environment based on the approach of centralized 3D-CAD master models, which efficiently allow the simultaneous representation and alignment of involved parts and components. The present publication introduces to different levels of knowledge-based design methods, reaching from parametric geometry models up to comprehensive interactive applications including CAD-templates. As a key aspect of this publication, a knowledge intensive approach is presented, which points out the potential of advanced knowledge-based design methods. In particular the highly integrated approach uses a novel configuration of a design-related master model that connects several development disciplines and simultaneously enables the handling of complex product-related interdependencies. A central problem-oriented application offers a user-friendly interface that supports the automation and control of the entire product design process.

Keywords: complexity, computer aided design, knowledge management, knowledge-based design, design efficiency

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1 INTRODUCTION

The virtual development of complex products is characterized by numerous influencing factors which can either stem from internal boundary conditions like product specifications or from external requirements, e.g. standards, regulations or specific customer-demands. In addition, the different components and modules of complex products can have functional and geometrical interdependencies, but are developed in different departments, respectively by application of different engineering disciplines. Due to the development within different environments, the impacts of product-related modifications and variations are often difficult to understand and traceable. Considering the requirements of data consistency throughout the development process, updated development statuses of each component have to be aligned continuously which can cause enormous efforts through data and information transfers.

To give an example for the implementation of efficient, CAD-based development methods, the present research work concerns actual challenges within automotive seat development. Automotive seats represent the main interface between human and vehicle and thus their development calls for an outstanding attention. In this way, specific ergonomic requirements regarding anthropologic aspects as well as comprehensive legislative regulations e.g. from vehicle safety issues have to be considered. The strong interdependencies of geometrical and functional factors in combination with their varying definition in different technical areas lead to an additional challenge. Each design change of the seat model causes extensive analysis and validation loops, which are performed in different software environments of specific engineering disciplines. For example, even a relatively simple feature, like the safety belt track, which depends on geometrical factors, the size of the passenger and ergonomic aspects, has to be recalculated with every design change. This task assumes the consistency and availability of extensive geometry data, which states an enormous challenge in early development stages. In today's development of complex mechanical or mechatronic products, several product-related data are centrally administrated in process-oriented PDM (product data management)-systems, that do not consider an alignment with regards to technical-oriented content, e.g. the alignment of geometry updates. These boundary conditions call for the development of new approaches which use so-called integrated 3D-CAD (3-dimensional computer-aided design) master models as central product representation. With the target to investigate advanced design methods, our research methodology is based on the possibilities for enhancement of CAD models with integrated engineering functionalities. In the present approach, a comprehensive product representation is implemented into a CAD model structure, which includes the consideration of geometrical and functional characteristics. This master model serves as a central tool for the entire layout and development and supports the investigation of specific engineering challenges. To meet this task, the CAD model includes much more than purely geometrical information; it is enhanced with a variable, parametric-associative geometry control, knowledge-based features and automated routines, which are programmed within the CAD software. In this way, specific user-friendly solutions are prepared, which can be accessed without any data transfer between different software environments. A specific challenge in the development of such tools represents the integration of stable geometry parameterization and algorithms, which are able to support the engineers by the provision of geometry-based recommendations and solutions. In addition, the complex interaction of different parameters and dependencies requires the implementation of an external programmed user-friendly control strategy, which enables access of users that are not experts in CAD-oriented programming methods.

Generally, the approach of a master model configuration as central product definition is not new. Hoffmann and Joan-Arinyo (1998) developed an architecture including a centered product master model around a server and a data-repository that is connected to downstream clients like CAD-systems or manufacturing process planners. They focused on keeping consistent information of different domain-specific programs and methods to maintain design changes efficiently.

Lee (2005) presented a CAD-CAE (computer-aided engineering) integration strategy. He proposed a single master model that allows the interactive creation of different types of geometrical models required in external CAD and CAE environments. In this way the approach was able to reduce duplicate effort of common CAD- or CAE-centric approaches.

Novel knowledge-based master model approaches enable automated coordination of multidisciplinary analyses, like the work of Sandberg et al. (2011). In this work, a central CAD-based master model enables the creation of analysis models by the example of dynamic finite element analyses. Both citied

work show automatized analysis approaches from pre- to post-processing, based on commercial CAD environment with integrated CAE functionalities.
The mentioned publications are just an extract of several master model approaches in literature. Many of these publications have in common a central governing product master model with the focus on a derivation of analysis models for internal or external CAE applications.
Main idea of our strategy is the creation of a highly integrated CAD-based master model that provides a comprehensive engineering environment for complex products, which can be applied over the entire development process. Goal is to integrate the required analysis and validation features into the model, especially to support initial development stages by enabling efficient design studies or “what-if” scenarios. One idea of the present approach includes the implementation of sub-modules for CAD-based approximation resulting in a lower level of detail, but delivering sufficient exact results for early design phases. In contrast to previous publications, our approach can be used as central development tool in which the actual, comprehensive development work is performed. In this way several design, analysis and validation tasks are carried out within one CAD environment, which leads to short verification loops. This requires an intensive integration of knowledge into the master model, which increases its complexity. The complexity of advanced CAD-models based on deep product structures and parametric geometry can lead to instability of the product model, causing update errors for example. To keep up the high degree of automation, the present approach includes methods for managing the complexity and model stability. An additional interactive application unit bundles and filters any occurring errors for a user-friendly prepared response message.
In this way, the present publication contributes an additional integrated master model approach to the mentioned state of the art focusing on complex products with a high degree of stability and automation.
This article starts with an introduction to the comprehensive capabilities of advanced knowledge-based design (KBD) methods and points out their potential for modern design processes. Section 3 describes the architecture of the design-related master model approach followed by the description of its key aspects: an interactive application for process control and automation as well as a management of product, geometry and parameter stability. This section closes with an exemplary application of the approach in automotive seat development. Finally, the significant findings, benefits and limitations are discussed in a short conclusion.

2 KNOWLEDGE-BASED DESIGN

Knowledge-based engineering in general includes a technology-oriented focus on methods and tools for the support of product development. Knowledge-based design in particular concentrates on product design and its related procedures. In this way, knowledge-based design supports design processes by re-using predefined methods, algorithms or results, and it is integrated into specific tasks or workflows that are involved in the design processes. Knowledge-based design methods and tools can include the use of rigid or variable geometry data, the integration of calculation and simulation procedures into the design process, or the application of problem-oriented software solutions that can be integrated into the design environment. Besides geometrical modeling tasks, knowledge-based applications can provide functionalities that integrate procedures, which were previously accomplished via separate calculation or simulation software.

2.1 Levels of knowledge integration

Due to its wide range of functionalities and applications, one finds different definitions of knowledge-based design in the relevant literature. On the one hand, knowledge-based design starts with the parameterization of geometrical objects in the course of the design process. On the other hand, the creation of extensive, problem-oriented simulation algorithms within a design environment represents a transition into complex software applications. In this way, the creation of different types of knowledge-based design methods and tools enables the handling of specific task. Different types of knowledge-based design applications can be grouped in terms of the effort required for creation and maintenance, as well as the level of complexity. The class of rigid geometry models includes different types of 2- or 3-dimensional non-parametric geometry models, which are provided for re-use in databases. Because rigid models represent carry-over parts or simple standard components, the creation and maintenance effort is limited to organizational tasks and data provision. Variable geometry models include the predefined configuration of geometry-driving parameters to achieve variability of geometrical characteristics. Besides the effort for geometry-related design, which mainly addresses the development of the product shape and function, the creation of variable templates is more complex. In addition, variable geometry models include parametric control of geometry-defining parameters, which are open for user editing. Integrating mathematical or logical relations into variable geometry models by implementing formulas, rules, reactions or check operations provides a significant potential in terms of supported geometry creation. Logical relations and the mathematical combination of parameters, which define the dimensions of the design model, expand the control of geometry by input parameters. Automated routines for geometry creation or calculation procedures are performed by integrated scripts (e.g. Visual Basic for Applications (VBA) scripts), which are configured according to the requirements of logical software development. Automated routines are implemented in template models and require some maintenance and update efforts. Unlike automated routines within CAD models, interactive applications are programmed within the applied design software and therefore they are supplied independently from the actual geometry models. Interactive applications represent problem-oriented software solutions for specific tasks. These software solutions are characterized by graphical user interfaces (GUI) for user-friendly handling, professional parameter management and integrated calculation or simulation procedures. If necessary, CAD-external software packages or databases can be connected using bi-directional data interfaces. In this way, interactive applications enable an integration of CAE into CAD processes.

2.2 Knowledge integration using template models

Template models represent a kind of master models that can be integrated into development processes. Template-based development methods are used in various domains (e.g. design, simulation, software development). The present publication focuses on design processes, whereby the ability of modern CAD software to perform calculation and simulation procedures using design templates enables an integration of CAD and CAE. Here, template models are understood as predefined design model structures or geometry models, which can be augmented with additional functionalities.

2.3 Implementation of mathematical and logical relations

The definition of mathematical connections between parameters enables the implementation of logical geometrical dependencies. In this way, formulas, relations, rules and reactions are integrated into the CAD model environment and support automated geometry definition processes. This can lead to a reduction in design effort in the case of variant studies or the re-use of parametric models. Besides purely geometry-related characteristics, these enhanced parametric models can include additional knowledge about dependencies and relations between different design-related aspects. Besides standard functionalities for the implementation of mathematical and logical coherences, the integration of (internal or external) problem-oriented solving procedures into the design process supports recurrent operations in the course of development and optimization cycles. In the case of internal calculation procedures, the mathematical algorithms are embedded in the CAD environment, which facilitates a direct access to the implemented functionalities. Internal solving algorithms use the functionalities of the CAD system to specify user-defined procedures and calculations. These can be simple linear calculations of dimensional values or enhanced mathematical algorithms, which are embedded in macro-controlled software sequences.

2.4 Programming of automated routines

The ability to create macros is very helpful for enabling automatic sequences of features and actions. Most of the advanced CAD software packages offer programming languages or editors, which support the creation of effective and versatile routines (e.g. VBA, VB.NET). Macros can control recurrent operations in virtual development processes. The integration of these programs into the CAD software enables their integration into the virtual model, while the data flow in assembling structures and between other types of CAD files supports the generation of efficient tools for specific problems in the development process. An automated handling of problem-oriented mathematical connections, formulas, rules and algorithms can be implemented into the corresponding product model to provide significant support for the layout and design phase. In addition, the creation of graphical user interfaces and macro-specific toolbars in the design environment supports a user-friendly operation.

3 KNOWLEDGE INTENSIVE APPROACH IN PRODUCT DESIGN

As previously mentioned, this paper focuses on the improvement of virtual development processes of complex products. Such products are built up of several sub-products and components which are characterized by a considerable number of influencing factors. Internal dependencies between correlating components and modules in combination with external influencing factors, which exemplarily stem from legal requirements, regulative boundary conditions or customer demands, can lead to system constellations with complex and even unclear relations of participating entities. As a consequence, the impacts of varying system parameters are difficult to retrace and therefore the input of expert knowledge through the development is often indispensable. In this way, the range of possible (experienced) users in design of complex products is limited which can involve higher development risks. The development of the related sub-products and components is typically performed in different development teams and system environments. According to the requirements of data consistency and data integrity, the continuously balancing and adjustment of actual component data status is necessary. Regarding the development of multiple variant studies, this leads to increased effort and therefore to reduced development efficiency. In addition, these circumstances can lead to a limitation of design quality related to early development phases which are often characterized by reduced product information and high degrees of development freedom.

Derived from the concluded challenges of complex products above, some general requirements on the implementation of product models can be determined. On the one hand the goal is to develop a method that leads to increased development efficiency, by implementing as much knowledge from experts and other knowledge sources. On the other hand the simultaneously increasing complexity of the applied methods must be prepared user-friendly to enable an efficient handling of the rising amount of information throughout the entire development processes. This can be achieved by the implementation of methods and algorithms, which lead to a simplification of complex relationships, without neglecting relevant information. In this way, a certain degree of ease of use can be reached to support engineers, which are not primary involved to the complex design methods but bear responsibilities of product-development related decisions.

3.1 Design-related 3D-CAD master model

This section presents an approach that constitutes the possibilities and potentials of the introduced types of knowledge integration to accomplish the requirements of developing complex products. The widespread utilization of CAD-systems in virtual product development and their abilities of knowledge integration and automation offer a suitable basis for this approach to be based on 3D-CAD. One key to an effective coupling of design-influencing aspects can be the use of a centralized master model, which contains the product geometry, as well as additional information. The realization of master models in 3D-CAD environment is based on the fact that the product itself including its geometry and structure continuously is in focus of the entire development process. Master models not only contain geometrical information but also function-, production- or process-related metadata, depending on their field of application. Figure 1 shows the configuration of a design-related master model, which can be used for the development of complex mechanical products. A 3D-CAD based geometry module for visualization and calculation as well as a related data repository represents the main integral parts of the model.

3.1.1 Geometry section

A pre-defined main-module of geometry section includes all components and modules of the entire product, represented as 3D-CAD components, and therefore it characterizes the actual product development status. At least those components with strong functional and geometric interdependencies are content of this module. The geometry section simultaneously serves as an assembly structure template where the modules or components of the product can be arranged and managed. In this way, the entire product structure is defined at the beginning of the development process and can be filled gradually with geometry data with increasing maturity. Due to the fact, that in initial phases product geometry is only partially or not defined, additional parametric substitution geometry data is integrated to this main-module. These variable geometry models, in terms of component and assembly templates, enable a temporary substitution of all product components and can be hidden after stepwise creation of the original components in shape of rigid or variable geometry models. In this way, continuously meaningful alignments considering important influencing factors, can be performed due to a permanent representation of the main-components among the integrated geometry section. Characterized with a high degree of freedom by means of geometry parameterization, these centrally controlled geometry models allow an effective elaboration of variant studies and consequently they are able to increase the efficiency of the development process.

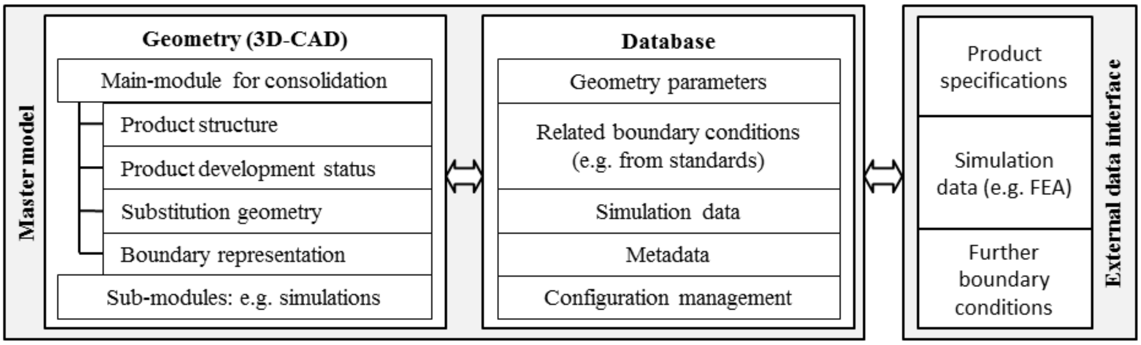

Figure 1. Design-related master model configuration

The consolidation of geometry data within a highly integrated geometry module for the alignment of product related data is not less caused by the idea of checking the actual development status. Therefore the entity boundary representation in Figure 1 is represented by geometry data in the master model structure for the visualization of predefined boundary conditions to enable spatially-based checks of product geometry positions for instance. Sources for those conditions can stem from internal product specifications or different development disciplines, e.g. a maximum length of product overall dimensions, as well as from external standards and regulations. In particular, such geometry representing boundary conditions are effective by simultaneously depicting different standards, exemplary in case of disposing products in global markets with specific requirements. Caused by the integration into one structured template the boundary geometry can be related to all implemented products, even to the parametric substitution geometry. Furthermore it can be implemented using simple rigid or variable geometry templates up to fully integrated mathematical and logical routines.
An additional benefit of a design-related master model is the integration of simulation- and calculation-procedures into the 3D-CAD environment. Background of this simulation-integrated approach is the focus on early development stages in combination with a comparatively low required level of detail. The goal is to enable short simulation cycles in early phases due to geometry-based simulation procedures with adequate level of quality and significance. Especially the integration of kinematic investigations is very efficient, e.g. for products which are using slope or switch mechanisms, where small deformations can be neglected at the beginning of development. Due to the integration into sub-modules within the geometry section, the former extensive data transfer can be omitted which enables advantageous short development cycles, particularly regarding variant studies. In addition, CAD-external simulation processes are supplied with required information by use of integrated data interfaces. One important feature of the presented master model approach is the organization of geometry parameters in a pre-defined order, which includes a consistent parameter structure in each component and assembly level, as well as a centralized parameter structure in the main level of the product assembly. This centralized parameter structure is used for direct information exchange with an associated database.

3.1.2 Database section

The data exchange between geometry and database section can be performed in both directions. Depending on the degree of automation, the database section can be directly connected with the geometry section or centrally controlled by a problem-oriented knowledge-based interactive application as presented in the following section. Within the framework of this design-related master model, the data repository contains several product-related parameters. The configuration in Figure 1 shows a selection of the types of data used for the present design-related master model. Numerous parameters for control of parameterized geometry, like a previously described substitution-geometry or parameters defining boundary-conditions regarding check geometry, represent the main content of this section. In addition, relevant simulation data or intermediate computation results can be included into the master model approach. All product-related data are tracked in a closed data set, whereby each of

them represents a certain configuration of the overall data status. Besides the role of archiving parameters, the database supports intentions regarding data consistency by a compact configuration management to provide common data status and consequently to ensure reproducible development results. In this way, the database serves as a central unit for storage and tracking of product characteristics and functionalities throughout the virtual product development process.
The entire master-model uses a bi-directional interface to external development tasks. External performed simulations, e.g. fatigue- or fluid-dynamics-simulations can be supported with actual product data from the master-model and vice versa the master-model is able to process delivered results within a design-related environment. Based on this interface, several boundary conditions, exemplary derived from production engineering, life-cycle related aspects, initial product specification or information sources, can be considered continuously.

3.2 Process control and automation

Based on the application of different knowledge-based design methods and tools in combination with related CAD-templates, the presented master model approach represents a potential basis for efficient design processes. However, a high degree of integration requires the administration of various information and data. As typical characteristic of complex products, this fact leads to a decrease of usability which can result in inefficient development processes.
In addition to the architecture of the introduced master model, a further key element of the present approach is represented by a problem-oriented application as central control unit, illustrated in Figure 2. Using highly-integrated knowledge-based design methods, this interactive application enables an efficient management of the centralized master model supported by a target-oriented user-friendly GUI (graphical user interface). Due to this, not only super-users but also persons that are not primary involved to the underlying design methods are able to handle the entire system. A bidirectional data interface of the application ensures the management of the automatic controlled design-related master model in terms of separated access to database and geometry section. The latter is built up of a 3D-CAD model for the support of the central data alignment and representation as well as possible sub-modules for different purposes (e.g. simulation). The ability of external controlled master model entities allows the avoidance of fixed linkages and interdependencies. Hence this approach enables a flexible configuration considering the entities' location or maintenance operations. Besides the management of master model-related tasks, this configuration is able to provide several possibilities of data exchange, like the import or export of parameters or CAD-data. Furthermore, the approach can be connected to product data management systems to enable the exchange of different project data, supporting the actual data status.
The adaptive bidirectional interface is controlled by internal routines and procedures as part of the application, as depicted in Figure 2. Core element of these functions is represented by a comprehensive parameter management unit which enables the handling of all parameters related to the integrated master model. Besides the main idea of exchanging parameters between CAD-environment and database, this unit administrates several parameter changes coming from user inputs or other sources, e.g. results from sub-modules (e.g. for simulation). In this way it serves as a basis for additional internal routines of the application. An implemented CAD-document management enables the administration of all involved CAD documents of the master model by opening and closing the actual required documents according to the performed function. Out of this, the present approach allows a splitting of the sub-modules into several CAD-documents which enables an adjusted load of the workstation and thus an efficient usability even for computers with limited resources. In addition, Figure 2 includes several functions for the management of the master-model's database. Using the bidirectional data interface, an internal database management provides functions for archival storage, tracking of parameters or supports the exchange of datasets to further locally installed master model databases of the same type. The main idea includes the deposition of all CAD documents on local workstations to prevent user conflicts within CAD environment. In contrast to the CAD documents, the entire data section of the master model can be located on a centralized server. Each user of the local- or server-installed application is connected to the central located database. In this way requirements for collaborative engineering can be supported and an efficient data exchange among the treated product, especially in early product development phases, can be achieved. As an important feature considering process integration, the present approach is able to perform transfers to external environments or applications which are handled by an implemented data exchange management. In

this way, the application can be connected to traditional PDM-systems, exemplary for exchange of actual project data. For additional specific purposes the application allows an import or export of master model parameters or geometry data. Extracts or imports / exports of data status from the database can be performed in form of native or neutral CAD, depending on the available features.

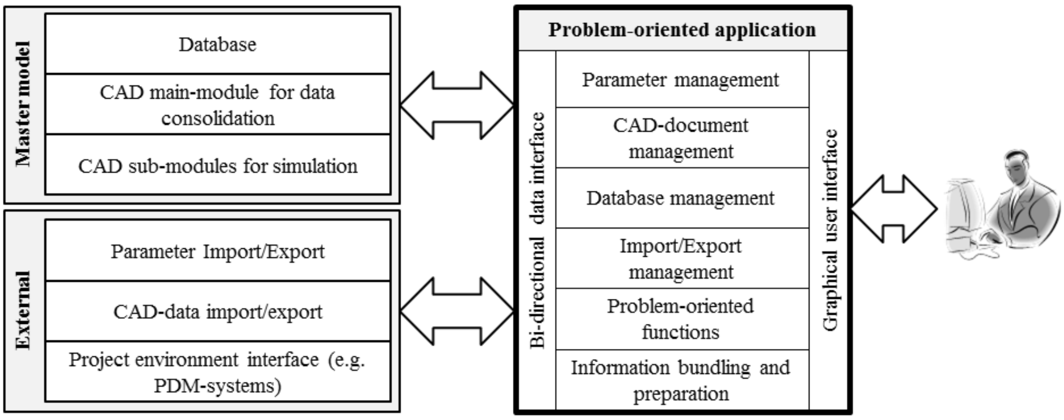

Figure 2. Problem-oriented interactive application as centralized control unit of the design approach

Several units of this application offer a wide range of functionalities which can be supported by automated routines. A main reason for the process control and automation using an interactive application includes the implementation of problem-oriented functions. For example, such routines are represented through automatic archiving or preparation of actual datasets including the automatic creation of drawings in combination with user-defined visualization features, controlled by the graphical user interface. Specific functions can be implemented to handle the simulation data of sub-modules, to manage comparing parameters by means of different datasets or to support simple but effective features like parameter reset or calculation of recommended parameter values. Furthermore, the present application contains another key element for filtering and preparation of the handled information. In particular, this functionality is represented by routines which support the user by feeding the GUI with parameters and information. In addition, this feature serves as data-filter to prepare meaningful and user-acceptable information. Latter is necessary due to a novel kind of handling complexity and stability of the presented approach as described in the following.

3.3 Management of complexity and geometrical stability

In this section, a method for the management of the introduced approach is presented, which supports geometric representation and user-friendly handling of complex interdependencies by a simultaneously perpetuation of geometric stability. Product complexity is not only characterized by numerous sub-components but also through complex relations between influencing factors which often have to be represented on component level. In the same way, the implementation of complex relations on component level of modern parametric-associative 3D-CAD environments is very suitable due to a wide range of available knowledge ware in combination with the parameterized geometry.

The present method is based on the intensive usage of the introduced KBD-types. As shown in Figure 3, a comprehensive functional CAD-template states the core element which contains the parametric geometry. Several boundary conditions, which stem from various standards or user-defined pre-definitions, are managed in an internal unit for knowledge preparation. This one contains various calculation functions to prepare the complex interdependencies for the control of the parametric geometry. The control of comprehensive parametric geometry as well as the handling of mathematical and logical relations can cause geometry errors due to instable geometrical constellations, e.g. undesired geometry-intersections. In this way, an erroneous constellation of the user's input can lead to a crash of the CAD-model and furthermore to a time consuming debugging. To avoid this behavior and to ensure effective error prevention, the introduced method contains a combination of KBD routines. In particular, the CAD-template includes a problem-oriented geometry and parameter monitoring unit by use of integrated conditions for stability by application of logical checks. The results of these checks are handled by the presented interactive application and visualized in the GUI to inform the user. Considering complex geometries with several degrees of freedom, there can occur numerous checks in the template, which have to be prepared for user-acceptance.

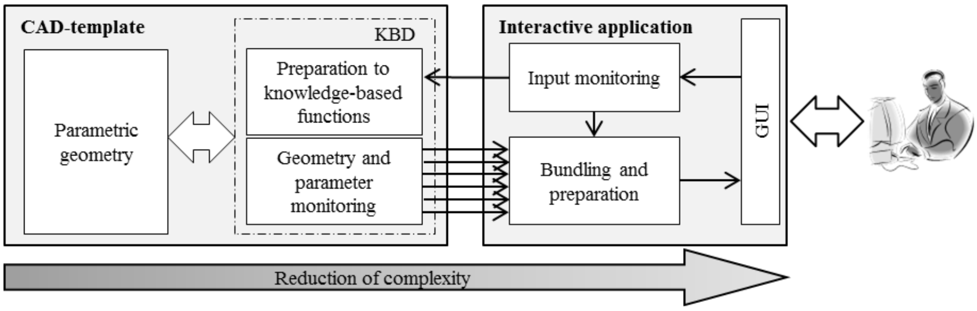

Figure 3. Knowledge-based method for handling of complexity and stability

An according unit which is integrated into the presented interactive application bundles the complex response of the template to prepare a simplified feedback message for the user. This enables the engineers to a target-oriented optimization of parameter inputs. In addition, the method uses an input monitoring unit which prevents obviously faulty insertion to the application. This novel method of monitoring and feedback preparation for the operators enables an efficient application of the presented master model approach. Considering software maintenance, the centrally controlled interface reduces the maintenance effort due to neglected fixed connections between CAD-documents. In addition, the template-based structure enables an easy adaption according changing boundary conditions.

3.4 Example of application

As described in the introduction, the complexity of virtual seat development in automotive engineering serves as an exemplary application field of the presented approach. Based on the general configuration in Figure 1, an applied master model for seat development was created as illustrated in Figure 4.

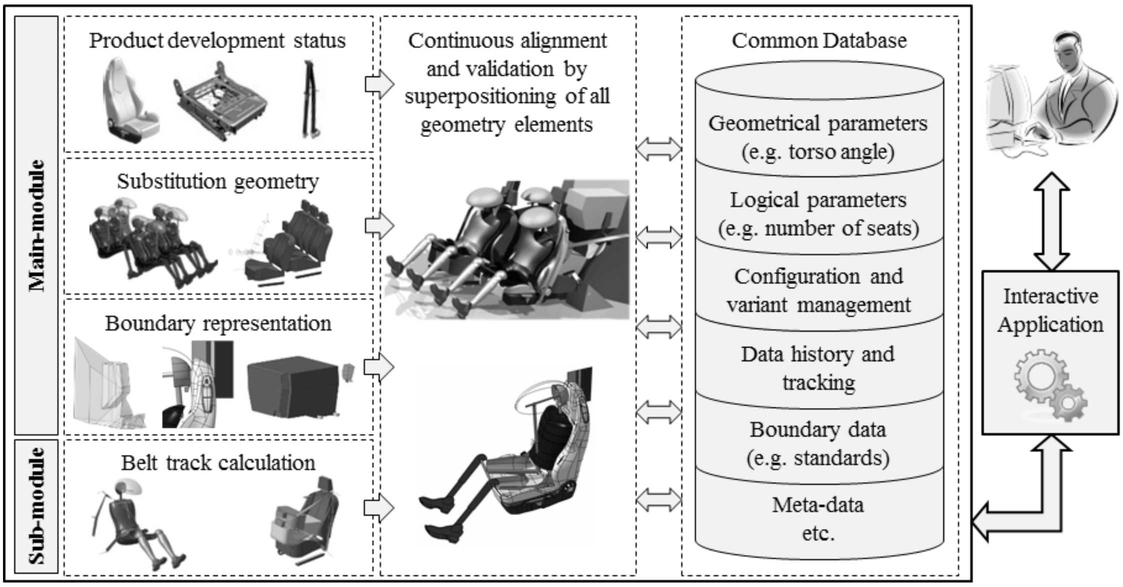

Figure 4. Master model configuration for seat development

The main module serves as working environment and contains the actual product definition. Implemented high parameterized substitution geometry is exemplary represented by conceptual seats or different virtual human models. A substitution geometry in combination with a check-geometry of a boundary representation module enable short verification loops in early phases, which were former performed in kind of trial and error. Exemplary the position of the head-restraint unit according to different global standards can be checked through a continuously performed super-positioning of all relevant geometry modules, as seen in Figure 4. With every design change, a CAD-based sub-module calculates the actual belt track according to the defined geometry parameters. Generally this procedure is performed by use of a detailed and verified commercial finite element tool. One idea of our approach is the replacement of detailed CAE-tools by CAD-based approximations to get sufficient exact results in early stages. In this way, the application of extensive, CAD-external commercial tools can be restricted to homologation procedures in a final phase of development. Based on the continuously centralized representation of involved components and parts, this application allows a fully automatized derivation of sectioning drawings as presented in (Stadler et al. 2012). Several logical and geometric parameters of the master model are administrated and stored in a bidirectional connected database. The parameters are bundled to configurations to enable traceable variant studies including data tracking functionalities. The entire master model is controlled by a problem-oriented CAD-external database application, which uses the integrated KBD functions in combination with the API (application programming interface) of commercial CAD software.

4 CONCLUSION

The present article presents a knowledge-intensive approach that supports the virtual development of complex products using the idea of a design-related 3D-CAD master-model in combination with a novel method of process control and automation by means of complexity and stability management. In particular, complex interdependent relations of parameters are handled and prepared user-friendly to keep up a continuous efficient development process. In addition, occurring geometrical errors, i.e. coming from inconsistent geometry, are avoided by a stable parameterization strategy in combination with automated control algorithms. This approach allows a user-friendly accessibility within complex product structures; not only to typical clients like design engineers but also to clients that are not primary involved to the development methods, but which may bear the responsibility of product-related decisions. As the benefits of the approach mainly lie in the conceptual development, its capabilities in series development stages are limited. For example, detailed analysis methods, like an evaluation of comfort under dynamic conditions, have to be performed by use of external simulation software packages. For such detailed simulation a strategy for CAD-CAE integration and an automatic pre-processing of external analysis models will be integral parts in future work. The present approach has been exemplarily applied in automotive seat development, leading to an increase of working efficiency, in particular in terms of collaborative engineering through early development phases.
It is demonstrated, that a smart combination of different levels of knowledge-based design methods and engineering data interfaces enables the creation of effective development process control by use of integrated automatisms. In this way, the presented strategies are able to improve the efficiency of virtual product development cycles, especially during conceptual phases.

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