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COPING WITH MULTIDISCIPLINARY PRODUCT DEVELOPMENT – A PROCESS MODEL APPROACH

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ABSTRACT
The aim of this contribution is to introduce a novel process model developed by the research alliance FORFLOW (Bavarian research cooperation for process- and workflow support for planning and controlling procedures in the product development). This research alliance consists of six institutes of mechanical engineering and applied informatics of four Bavarian universities. We claim that the FORFLOW-process model is rather detailed but yet variable and universal enough to support multiple aspects during product development. It enables to deal with increased challenges in multidisciplinary development and provides broad situation-specific support. This is demonstrated based on typical challenges: "integration of mechatronic aspects", "situation-specific process planning", "integration of design iterations", "integration of lessons learned", "supporting aspects of Design for X", "support of CAx-aspects", "multi-level safeguarding" and "integration of simultaneous and concurrent engineering". By means of these topics the contribution will also focus on approaches that were developed to cope with these challenges. In addition to advantages of existing and known process models, these approaches are integral parts of the FORFLOW-process model. Furthermore, resultant possibilities and advantages as the dynamic connection between process model and different product models or the enhanced search quality are depicted.

Keywords: product development support, process modeling, multidisciplinary product development

1 INTRODUCTION
Development of modern technical systems has to face more and more increasing demands, for example made on costs as well as functional, aesthetic or environmental aspects. Associated with those demands is an increased complexity of products, which results in an increased complexity of related development processes: Since modules mostly are developed in parallel, interfaces between individual structural elements constitute interfaces in the product development process as well. Hence, due to the network of dependencies arising between the individual work steps the increased complexity of modern technical systems results in an increased complexity of the entire product development process. Furthermore there are various boundary conditions and restrictions that have to be considered as early as possible, which is hindered by the often unforeseeable and iterative progress of the product development process. Additionally, due to the often distributed development partners the interdisciplinary product development becomes more difficult. Another aspect to be considered is the increased application of computer aided tools in the development of multidisciplinary products. A multidisciplinary product development has to manage these challenges by innovation cycles getting shorter and shorter as well as by the permanently increasing quality demands. This short overview outlines a few aspects which are jointly responsible for steadily increasing challenges in the development of technical systems.
Hence, the aim of this contribution is to introduce a novel proposal for a detailed but variable and universally valid model of the product development process which provides support and assistance in multiple aspects during the development of technical systems. This process model combines multiple approaches on different challenges in multidisciplinary development and integrates them into a single process model which is claimed to be suitable to support modern product development. Furthermore, the dynamical connection between process model and product models and the thereby enhanced search quality are depicted.

2 ASPECTS TO BE CONSIDERED IN A PROCESS MODEL FOR PRODUCT DEVELOPMENT

As mentioned above, a lot of challenges in the development of technical products are handled by the FORFLOW-process model which provides an appropriate support of multidisciplinary product development. Subsequently, some of these challenges are addressed in detail. Due to the increased demands on part of the customers and due to the aspired components' functional integration, the amount of electrical, electronical or software-based solutions steadily increases. Hence, an appropriate support for product development has to be provided to deal with these mechatronic aspects. In addition, the development process proceeds often unforeseeable and iterative, which means that a fix and not adaptable process model is not practical for supporting product development [1]. Furthermore, an adequate process model for product development has to provide the developer with support in terms of questions regarding *Design for X* (DfX) and has to support a broad application of CAx-Tools. As mentioned above, the multidisciplinary product development often takes place simultaneously and is distributed across different departments, company branches or even different companies. Hence, there is an obvious need to support this contemporaneous distributed development of different parts of the product as well as to manage their specific safeguarding.

There are several different approaches to provide appropriate process models for the support of product development processes. Besides the V-Model XT [2], the approach by Pahl/Beitz [3] and the model of systems engineering [4], especially the VDI-Guidelines 2221 "Systematic approach to the development and design of technical systems and products" [5] and the detailing VDI-Guidelines 2222 [6] and 2223 [7] have to be mentioned. Another approach is provided by the VDI-Guideline 2206 "Design methodology of mechatronic systems" [8]. Further analysis proved that these approaches are not optimal for detailed support of multidisciplinary product development. This is – amongst others – caused by their missing detailed assistance due to the claimed universality of these process models.

The following section will introduce a proposal for a product development process model developed by the research alliance FORFLOW in cooperation of four universities. In contrast to other analyzed process models the FORFLOW-process model claims to be detailed enough to provide broad assistance, but still generic enough to be adaptable for universal use.

3 A PROPOSAL FOR A PRODUCT DEVELOPMENT PROCESS MODEL

The FORFLOW-process model is to be considered as one possible modality to cope with the challenges shown above by means of a process model. The main focus during development and formulation of the FORFLOW-process model was the question how to support the developer by means of a process model. The specific challenge in developing a process model is to solve the conflict between being as detailed as possible and contrariwise being generic enough to be adaptable to different tasks. In this section, firstly the design of the FORFLOW-process model is depicted, whereas the contribution focuses on the challenges of the developed process model and its advantages.

3.1 Design of the FORFLOW-process model

To provide an adequate detailing, the partial steps of the FORFLOW-process model are arranged in three levels (figure 1).

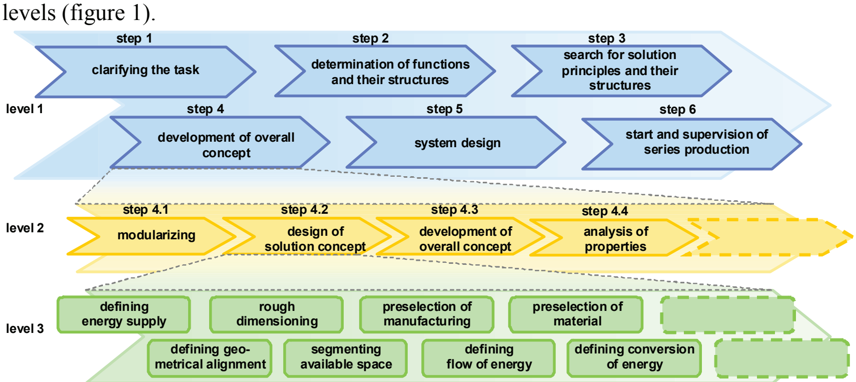

Figure 1: three-level-design of the FORFLOW-process model

The first one consists of six main steps that guide the developer through the development process, starting at clarifying the development task up to the start of production and – if needed – the supervision of series production. The second level consists of a number of more detailed steps, whereas the third level contains nearly 90 partial steps which guide the developer through the complete development process. Steps arranged in first and second level of the FORFLOW-process model are recommended to be executed in a certain order, for steps arranged in the third level there is no recommended order. The high number of partial steps enables to provide accurately tailored support to the developer. Due to the popularity and the ease of learning and to assure its common development, the FORFLOW-process model is prototypically modeled in ARIS-notation (figure 1 shows a schema of the process model, not ARIS-notation). For further information about ARIS-notation consult for example [9].

3.2 Challenges in the product development and approaches realized in the FORFLOW-process model

As shown above, the multidisciplinary development causes manifold challenges that a process model has to deal with. In this section, the chosen approaches coping with these challenges are depicted in detail. Furthermore, the advantages that a multidisciplinary development can take from the solutions implemented in the FORFLOW-process model are shown.

Integration of mechatronic aspects

Development of modern technical systems has to face more and more multidisciplinary demands, for example made on speed, precision, robustness, autonomy, and adaptability of the products. Associated with that is an increased penetration of those systems by electrical, software-based and electronic components. From this follows the challenge to integrate many different domain-specific solutions within one product and consequently the demand to integrate all involved domains in the development process. When guiding the developer through the step "development of solution concept" (figure 2), the FORFLOW-process model contains steps regarding e. g. available space, preselection of material and manufacture or rough dimensioning. To consider mechatronic aspects as early as possible in the development process, the FORFLOW-process model also contains the following partial steps providing special information for multidisciplinary development: "defining flow of signal", "defining signal processing", "defining software concept", "defining energy supply", "defining flow of energy" and "defining conversion of energy" (figure 2). Later, when developing the products´ overall concept, the FORFLOW-process model also asks to freeze the interfaces within the product and to clarify the domain responsibility for each function. Furthermore, when safeguarding the product being developed, the FORFLOW-process model prompts the developer to check the capability of integration and to consider interdependencies between the factors material, energy and signal. By containing these partial steps, the FORFLOW-process model has the ability to provide some detailed and specific information concerning the consideration of aspects arising with the challenges in mechatronic product development.

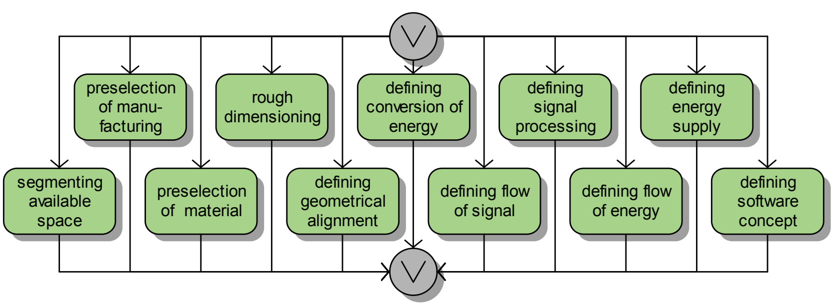

Figure 2: development of solution concept (ARIS notation)

Situation specific process planning

The FORFLOW-process model is designed to enable a situation-specific planning of product development processes. That means that the process planned at the beginning of a development project can easily be changed if there is a change in the design situation. Planning the development process for a certain development task begins with arranging the steps of the developed process according to the task at hand. In order to achieve this first tailoring of the process there are different kinds of process steps defined in the FORFLOW-process model. There are steps that have to be carried out so that a producible product is the result of the process, e.g. the detailed design of the product parts. Then there are process steps that are highly recommended but not absolutely essential as for example working out a functional model of the product. These process steps are not absolutely necessary for the adaptation of a simple sub-assembly but should be carried out if the product to be developed is a very complex one. And finally there are process steps that can be carried out but are could be of less interest in some cases, e.g. the abstraction of the development task. These should be carried out in development of new products. With recommendations concerning the optional process steps the process can be planned roughly. As mentioned in section 3.1, due to the recommended order of the partial steps arranged in the first and second level, a recommended process order is given. In some of the larger process steps as “development of overall-concept” the sub-steps of the third level are defined but the sequence in which to carry them out is not determined. The sequence is derived from the actual design situation. The situation is defined amongst others by the parameters:

- risk
- kind of development
- type of product
- persons working on the project
- workload

These parameters are defined either by the project manager (at the beginning of the project) or the engineer (while carrying out the process). The process steps are arranged according to the design situation and thus reacting to changes in a project’s boundary conditions is enabled fast and easily.

The process sequence is derived from a Dependency Structure Matrix (DSM) that displays the influence of the sub-steps on each other according to the situation at hand [10]. Clustering this DSM leads to a recommended process order. Process steps that relate strongly to each other (these are part of one cluster) are carried out simultaneously; steps that are not part of a cluster are arranged in sequence. By this a downstream information flow is enabled and upstream information flow prevented [11], which could result in a large unwanted iteration. Carrying out process steps simultaneously that are strongly interrelated shall support communication between the different tasks as these process steps depend on each other’s results. This is necessary as with the different disciplines working together in today’s product development an optimal solution cannot be found in one step. In order to give an idea on how situation and derived process are linked a short example will be given [12]: An engineer needs to plan the development process of a high risk, new mechanic product. In this case the recommended process steps are different from e.g. a low risk development of a mechatronic product variant. In the first case the recommendation could be to start work by roughly dimensioning the parts, whereas in the second case starting with the splitting of the available package space is recommended.

Integration of design iterations

The course of the product development process is not foreseeable in detail, is difficult to plan and develops iteratively in its progression. Consequently also a jumping back to previous sections of the development process can take place [13], [10]. The iterative procedure of the product development process materializes from boundary conditions, faulty decisions made on basis of unclear or uncertain assumptions only becoming concrete in the course of it. Furthermore, iterations are induced due to the high degree of division of labor and the associated lack of communication, by optimization potentials being recognized in later work steps or due to the fact that the solution for complex products often cannot be found in one step. Further triggers for iterations may be, amongst others, functional improvements, elimination of faults, changes in customers' requirements, or changing needs of the market [13], [11]. If there is a lack of support in handling design iterations, the development period extends and the traceability of the process is made considerably more difficult. But iterations on the other hand raise the level of information and are therefore rather to be considered as a learning process than an unnecessary detour. A process model providing an appropriate support has to be flexible as well as adaptable and has to support the developer in cases, in which the necessity of design iterations arises. To do so, the FORFLOW-process model contains multiple process interfaces that allow the developer to exit the recommended order and to return to certain process steps in terms of jumping back in the development process. The most promising step to jump back is recommended dependent on the actual development situation, but it is also possible to jump back to other steps. To ensure the acquiration of knowledge generated in these design iterations and to prevent avoidable iterations in further development, in the end each iteration contains a partial step which asks for documentation of the development process as well as for the generated knowledge. This acquisition of gained knowledge and obtained experience to prevent avoidable iterations can be seen as fundamentals for the integration of "lessons learned".

Integration of "lessons learned"

The FORFLOW-process model aims at the support of the documentation of "lessons learned" during product development. To do so a process step that demands the documentation of gained knowledge is established at the end of each of the large process steps on higher levels (e.g. detailed design). Including these steps puts emphasis on the necessity of preserving knowledge and experience obtained during product development. Moreover, the chosen process paths can be recorded, including planned and unplanned iterations during the process. This process documentation then can be used to identify "best practice" processes from the ones with short cycle time and low cost. These process paths can be recommended in later development projects and process paths that take a long time and lead to problems during a project can be avoided later on. If iterations are necessary during a process, the reasons for these are documented as well, in order to be able to warn the engineer in later projects against possible iterations in a similar situation.

Supporting aspects of Design for X

The term „Design for X "(DfX) stands for all methods, strategies and tools, which enable product developers to consider different important aspects and influences from different product life cycle phases at the same time [14]. "Design for X" is understood as knowledge system, in which realizations about attaining individual characteristics of technical systems are collected and arranged [15]. The task of product developers exceeds the fulfillment and conversion of function. For development of technically high-quality and innovative products it is indispensable to consider early parameters of partner systems ("X") [16] in early phases of product development (e.g. manufacturing, assembly and recycling). Therefore the consideration of DfX-aspects is already made in early phases in the FORFLOW-process model, e. g. while developing the product's overall concept. From different partner systems, various cognitions are obtained which have to be considered by the product developer in time.

The development process of complex products is based on decision making. In order to avoid unnecessary iterations, costs and additional expenses, it is necessary to enable product developers to realize the influences of all development conditions, which are the basis for decision making. Furthermore, it is necessary to consider these influences in decisions in the development process. By including aspects regarding "Design for X" already at the beginning of the process, these different assistances and supports regarding different X-systems can be made available to the product developers. To be able to obtain the optimum for the product and for all processes, it is necessary to support the product developers' activities during product development. Therefore the approach to support DfX-aspects is fixed in the FORFLOW-process model during the complete product development process. Especially in the late phases of product development a concrete DfX-support with elementary instructions is helpful for designing specific components. For instance, if a ceramic component is needed, specific knowledge about designing ceramics can be made available to product developers. These can be instructions like "avoid stress peaks" or "avoid material accumulations". The designer can also receive more detailed assistance like "induce forces on large areas", "avoid angles and sharp edges", "pay attention to constant wall thickness" or "avoid cross-sectional jumps". To implement several DfX-aspects, a methodic support is offered to product developers, which depends on the activity to be executed, for example evaluation or analysis methods. To make the DfX-optimization potentials for support of development process in the FORFLOW-process model useful, an approach was developed, which enables a process orientated integration of DfX-aspects and methods into the product development process [17].

Integration of CAx-aspects

As the global market is changing faster and faster and in order to remain competitive, another important challenge for a new process model in product development is the support of computer aided tools (CAx-tools). The previously determined DfX-criteria influence the choice of needed software tools and associated procedures. An essential part to provide an integrated product development process is the ICROS-Method (Intelligent CROss-linked Simulations) by which the necessary CAx-tools and the matching methods are linked [18]. Main goal is to fulfill the DfX-aspects as best as possible by appropriately composed CAx-processes. The origins of ICROS were based on the interdependencies of manufacturing simulation and computer aided strength determinations like the combination of injection-molding- and finite-element-simulation for fiber-reinforced polymers [19].
With the capabilities of modern CAx-tools and the complexity of innovative designs it is necessary to integrate best-use-strategies for these programs to keep the designer informed about dependencies of analysis results and DfX-related design tasks, e.g. a correctly adapted use of an assembly-simulation will also reassure the disassembly of the product. On the one hand this is realized by systematic provision of DfX elementary instructions during the part synthesis, such as design guidelines containing machining constraints and recommendations concerning the correct use of certain programs. On the other hand the designer is supported with manuals referring to the appropriate handling of analysis output. Subsequently procedures are provided containing improvement proposals. It is essential to provide the developer with the right information at the right time so that necessary modifications can be realized quickly and effectively. The use of in-house knowledge by adaption to the corresponding hard- and software equipment of an enterprise is stimulated.

Multi-level safeguarding

Due to the rising product complexity it is inevitable to consider a holistic view on the product. The corresponding mock-up of this product model is a multi layer approach, which considers the whole system, subsystems and single parts each on its own and their interdependencies. First of all the system is decomposed to the lowest level where the validation of the attributes takes place. Within that step the basic functionality of the part is analyzed as well as its machining properties and its supply chain, so that the companies' full potential can be used. These steps are repeated on all levels up to the main system (figure 3). Documented results of engineering analysis such as a strength determination are essential requirements for evaluation of mechanical components, as mentioned in VDI 2221 [5].

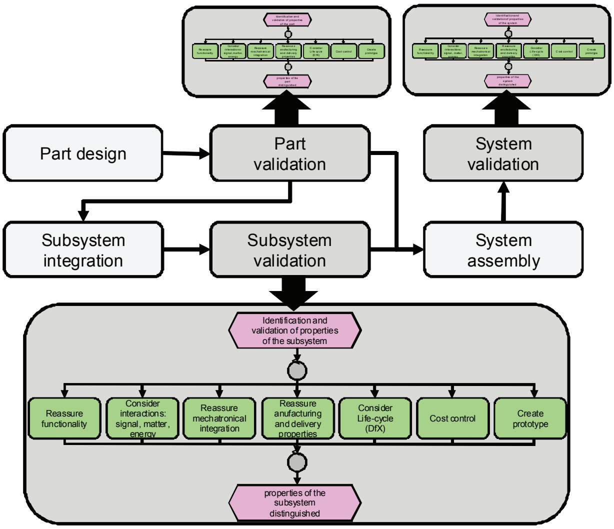

Figure 3: Multilevel and multi-domain approach (ARIS notation)

The sustainability and machineability of the parts are reassured. Innovative modern products do not only consist of mechanical parts and electric components but are mechatronic systems involving software both for steering purposes and for user interfaces. To assure the effective evaluation of such products the FORFLOW-process model has implemented a coordinated multilevel- and multidomain-evaluation. The holistic approach is targeted at checking all requirements and specifications made for the developed product. This means, not only those typical demands like functional and usability require-ments are considered, but also electric interaction, software compatibility and the crosschecking of machining capacities and supplier capabilities. The FORFLOW-process model's evaluation steps are carried out in a loop based on a combination of the top-down principal of the earlier product development steps and the bottom-up approach for product assembly. Each part is evaluated individually and then gets integrated in the corresponding subsystem which is evaluated on a parallel basis. The evaluated subsystem has to be checked to meet the standards of a functional mock-up [20]. When the complete product has been evaluated all required documents such as machining plans, software documentation and compliances to legal standards are available and can also be used for quality control. By using this bottom-up approach an extensive enterprise resource planning can be established.

Integration of simultaneous and concurrent engineering

For the support of the product development process there exist multiple methods. Enterprises that want to be competitive are interested in methods, which enable to shorten the development period and thus allow achieving an early market entrance for the product. Approaches for dealing with these demands are simultaneous and concurrent engineering. For implementation of simultaneous and concurrent engineering a set of methods can be used, such as quality function deployment, failure mode and effect analysis or target costing [21]. Next to shorten development periods the approach is aimed at faster product creation, economy of costs and quality enhancement. Therefore, it is necessary to fix the idea of the simultaneous and concurrent engineering already in the FORFLOW-process model. Hereby, simultaneous engineering is understood as the contemporaneous detailing of the product and the associated manufacturing process in consideration of resulting interactions [22]. To support simultaneous engineering, also the approach of integrating DfX–aspects can be considered as a suitable assistance. In contrast, concurrent engineering means parallelization and contemporaneous processing of concurrent executable process steps [22]. In the developed FORFLOW-process model this approach is fixed in the following steps "basic design", "sub-system integration", "overall-system integration", and "validation". Figure 4 shows a cut-out of the process step "sub-system design", where the steps "programming", "calculation" and "assembling" can be carried out contemporaneous and the step "calculation" allows to evaluate e. g. the product's compatibility for manufacturing.

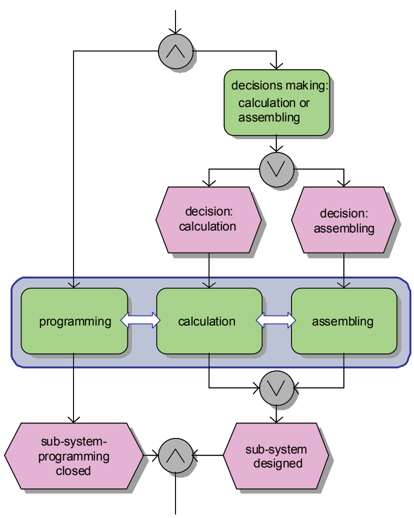

Figure 4: simultaneous and concurrent engineering in sub-system design (ARIS notation)

When developing mechatronic products the interfaces of several components are defined in the step "development of overall concept", as well as the responsible domain for fulfillment of certain functions. Thereby the components are developed and assembled in component designing and sub-system designing. The separate paths "programming" and "calculation/assembly" are processed in parallel, whereby product developers being in the right path (figure 3) have to decide, whether to start with calculation or assembling. A constant exchange of information is important between these parallel running steps. To achieve this, an approach on the control of iterations in the multidisciplinary development of technical systems shown in [13] can be used.

Dynamic connection between the FORFLOW-process model and product models

The FOFLOW-process model of this paper is an instance of a product development process, where the described aspects of product development can be demonstrated. It defines a most natural path through the development process, but considers also iterations and returns to earlier process steps. As shown above, in the context of this FORFLOW-process model, the planning of the actual sequence of process steps is situation specific and therefore can change during the execution. This flexible interpretation of a process requires dynamical product model integration. A dynamical retrieval of product models requires an adaptation of the links to the process during execution, which is not possible with current product data management systems or workflow management systems. These systems use either the product structure (no process relation) or link the product models to the process rigidly and do not allow changes during execution. Hence, the unexpected change of a process sequence leads to less relevant product models provided, since no relation between the product models and the process has been defined before the execution of the process. To bridge the gap of missing product information, a parameter based description method for product models has been developed [23]. The method applies the principle of a vector space to calculate similarities and relevancies of product models to process steps with the Euclidean distance. This allows automatic linking between product models and process steps independent from the sequence of the process. Furthermore, a flexibility of the linkage is provided, since changes of properties of product models are considered by the description method. Thereby, the application of the description method requires the users to describe used product models at the time they are created or changed. This leads to changes of the parameters during the process and the automatic new linking of changed product models to processes. This flexibility is needed to allow a useful information retrieval for the users, which displays the most relevant product models to the users. By using this approach, it is possible to adapt the information retrieval to flexible, iterative product development processes and assures the supply of relevant information without time-consuming process modeling workshops.

Enhancing search quality

Every new product design creates a multitude of documents and product data, resulting in an information overload an engineer is confronted with. Although reusable information might exist somewhere in the company, engineers often recreate data because they either do not know that information exists or where to find it. This is due to the lack of specialized search mechanisms that take into account all possible artifacts like documents, product data, or project information. Instead, there are partial solutions as simple search functionalities in PDM systems or 3D geometrical search engines. They focus only on one special type of engineering artifact and mostly do not include process information to generate better search results. Hence, searching in the domain of product development is no trivial task. Since there are many different types of artifacts an engineer is interested in, product development is characterized by complex search situations. While in some cases engineers need particular documents like existing CAD models, they especially look for data of a certain product (e.g. possible suppliers for this product) in other cases. But there are also situations, in which the engineers do not know exactly what they are searching for and therefore needs support to find information that is useful and relevant for their current situation. This requires both the possibility of a goal-oriented and an exploratory search based on context as well as content information of the artifacts. Besides the benefits mentioned in the section before, the FORFLOW-process model makes a contribution to improve the quality of search results. This improvement is achieved by several aspects realized in the FORFLOW-process model that are presented in the following.

A static assignment of product models to single steps of the process model offers two options for improving search quality. First, it helps identifying and describing information needs in product development situations. Second, the assignment results in more detailed information about the product models themselves, for instance in which process step the document has to be created the first time, in which steps it can be updated, or for which steps the document may be a useful information source. Both aspects enable domain-specific search support and can be realized as a search engine for the retrieval of all artifacts in product development. Therewith, an artifact can be described as a type of a search result, e.g. a *document*, a *product* or a *project*.
In addition to their content, these artifacts can also be specified by contextual information. In the examined case, this consists of process information which is linked with the artifacts. This information is gathered automatically by a flexible workflow management system whose concept is also developed in the research alliance FORFLOW [24]. In addition, user context information is available through that system as well and the development situation of the engineer can be described. A more comprehensive overview about the considered context information is introduced in [25]. The dynamic assignment of product model information (cf. section "dynamic connection between the FORFLOW-process model and product models") provides additional context information which can be incorporated during search and provides access to product models which do not follow the static initial assignment from the process model. This context information can be used in several ways during the retrieval step. A search mechanism can integrate context data to state the engineer's query more precisely. For instance, if engineers have to create a computer aided design (CAD) model for a certain part of the new product, they are situated at the step "component design", more precisely in the "design" stage. If developers want to search for eventually reusable parts, the simplest way would be to query for the name of the part that should be modeled. But, searching only for the name as keyword results in a plethora of data objects that are connected with this keyword in any way. This leads to a result set consisting also of documents only containing the name of the part, but not really relevant for the engineers in their current labor situation, like e.g. mounting instructions or bills of materials. By integrating the documents' context information, especially their process connection, the search engine can augment the user query. Alternatively the search engine could provide specialized search templates which are customized according to the information need of a certain situation in the development process. These templates consist of a pre-defined set of parametrizable search criteria. The user only has to provide the values for the specific problem he is seeking help for. The flexible workflow management system, which is conceptual developed in the research alliance FORFLOW, can provide contextual access to these search templates, when the user starts a process step through that system.
Moreover, as mentioned above (cf. section "integration of lessons learned") the process model explicitly supports the capture of lessons learned which contain gained insight or knowledge during development. A search engine can enhance this information with contextual information which depicts the situation where this information was generated more precisely. With the help of the developed flexible workflow management system, the search engine can determine an approximation of the current situation of the developer in future projects and can recommend these earlier lessons learned and therewith support the engineer in avoiding mistakes from the past. This provision can be triggered if the search engine detects similar projects because of similar requirements or tasks. In summary, it can be stated, that the outlined FORFLOW-process model enables more advanced search techniques which include contextual information to find domain-specific documents. The effect is a higher degree of reuse of existing knowledge and specifically parts and components from past projects which leads to shorter development processes and lower development costs.

4 CONCLUSION AND OUTLOOK

In this contribution, a novel process model was introduced, which has been developed by the research alliance FORFLOW consisting of four universities. This FORFLOW-process aims to enable developers to deal with the highly increased complexity of products and development processes. The main objective in the development of the FORFLOW-process model is to provide a broad, appropriate and situation-specific support for the multidisciplinary product development. Therefore, it was necessary to elaborate some central and typical challenges that have to be faced by product development. As main topics that are jointly responsible for steadily increasing challenges in the development of technical systems the following topics were identified: "integration of mechatronic aspects", "situation specific process planning", "integration of design iterations", "integration of lessons learned”, “supporting aspects of Design for X”, “integration of CAx-aspects”, “multi-level safeguarding” and “integration of simultaneous and concurrent engineering”. For each of these challenges the research alliance FORFLOW-developed appropriate approaches that are integral parts of the introduced FORFLOW-process model and were partly published and discussed already in earlier contributions on different conferences. Furthermore, some advantages of different existing and known process models were integrated into the FORFLOW-process model. The individual approaches and their integration into a single process model were demonstrated and resultant possibilities and advantages like the dynamical connection between the FORFLOW-process model and different product models or the resulting enhanced search quality were depicted. Altogether, the introduced FORFLOW-process model is rather detailed but yet universal and variable enough to support multidisciplinary product development.

Objectives of further research will be the detailing of the information that each process step needs to be carried out as well as the information that is generated by carrying out a certain process step. This could be information about the product’s properties, which can be gained, when these properties are attached to the product models that are connected with the FORFLOW-process model. Thus it gets possible to gain information, which process step generates, changes or needs certain properties as input. Furthermore, to enable the flexible workflow system to deal with responsibilities for the completion of process steps, it is necessary to attach roles to each process step, which is one of the next tasks to be carried out by the research alliance FORFLOW. Another important task in further research is to include the feedback received after deployment in day-to-day business at some of the research alliance’s industrial partners in order to improve and to adapt the process model to different use cases. Another objective for further work is the complete integration of the FORFLOW-process model into the flexible workflow management system, which is also developed within the research alliance FORFLOW.

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