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A FRAMEWORK FOR SITUATION SPECIFIC PLANNING OF PRODUCT DEVELOPMENT PROCESSES

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1. Introduction

The growing complexity of today's products and the need for a short time to market lead to an increasing complexity of product development processes. Thus, coping with this growing complexity of development processes becomes more and more important for companies in order to be able to face the international competition. Besides the requirement of the market for shorter product cycles, the increasing integration of electronics and software into formerly mechanic products adds to the growing complexity of design processes.

In order to meet these demands it is inevitable to deal with the process complexity and to be able to react flexibly to changes in the boundary conditions (i.e. the design situation) of product design.

This contribution introduces a framework for situation specific planning of product development processes that helps to enable companies in reacting to changes on the market, in customer needs and in other important constraints of product design. The framework as well as its implementation and evaluation are discussed.

2. Motivation

In order to be able to cope with the growing complexity of product development processes, it is necessary to develop new methods for process management. Existing approaches that support the management of well known business processes are often not applicable to development processes due to their specific characteristics. One difference between product development and other business processes is that the result of the process cannot be completely defined in advance (they are rather evolutional). Development processes are characterised by a high number of iterations (which cost a lot of time and money) due to changes in product requirements or the fact that some requirement is not met by the solution developed first or due to changes in the boundary conditions of a development project, to name a few. The framework for process planning introduced in this contribution supports both the reducing of iterations in design processes as well as the reaction to changes in the boundary conditions of a design project.

3. Objectives

In this contribution a framework for situation specific development process planning is introduced, that enables flexible reaction to changes in the design situation. A more flexible planning of design processes leads to shorter development time and better product quality. The framework supports two different levels of process planning for development projects. These are the project and the operational level of process planning (see chapter 4.2). It facilitates the instantiation of a generic process model for an oncoming development task and is thus applied at the interface of process and project management.

Other project management tasks as, for example, the assignment of resources to single tasks [Kerzner 2006], do not belong to the scope of this approach. Rather the main focus of the framework is to take into account the actual design situation and to enable a flexible reaction to changes in this situation during a product development project. Therefore, the framework consists of a generic process model of the product development process a description of the design situation and a procedural model for planning the process sequence of a development project. The different elements of the framework and their respective research background were published earlier, thus this contribution focuses on showing how the single elements interact with each other in a general framework.

4. A Framework for situation specific planning of product development process

In order to describe the framework for situation specific planning of product development processes it is necessary to introduce some basic ideas the framework is built on. This includes the underlying process model, the level of detail of process planning, the roles of project planning and operational planning as well as the description of the design situation and the basic procedural model. After introducing these basic ideas, the framework will be depicted and its evaluation discussed. Figure 1 illustrates how the different parts of the framework interact with each other.

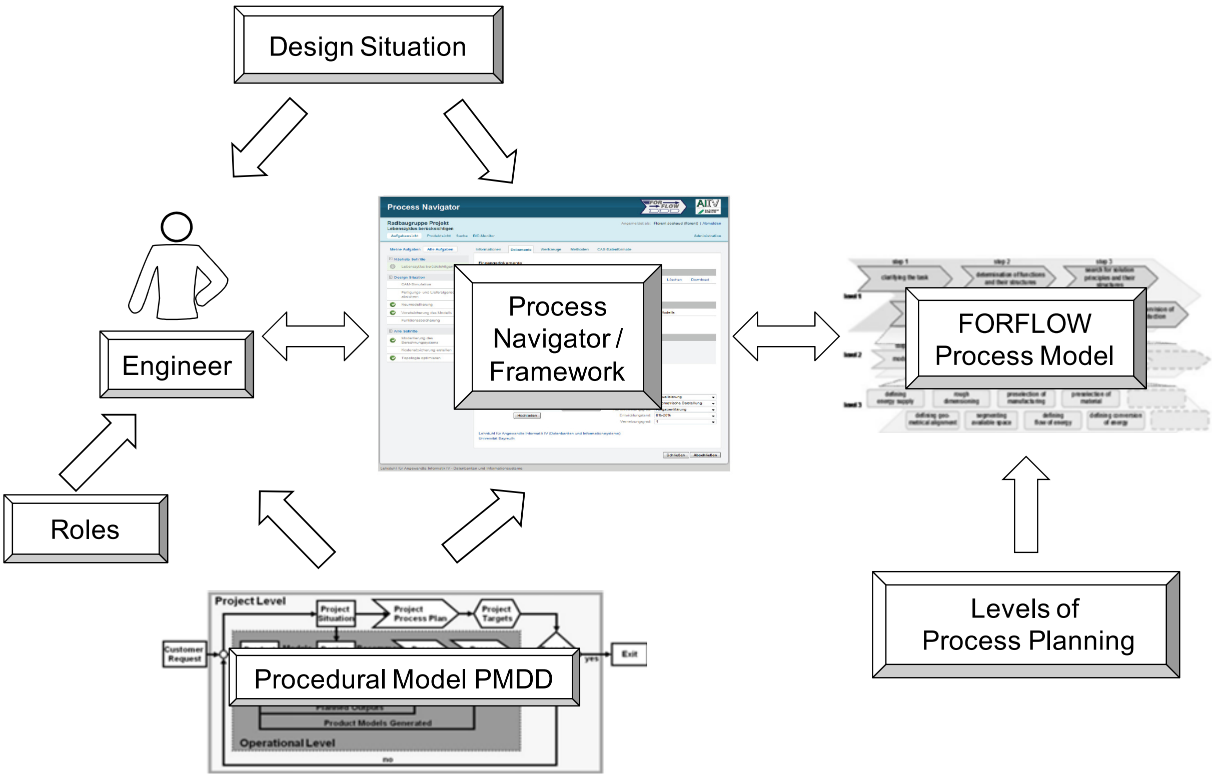

Figure 1. The elements of tthe framework for situation specific development process planning

4.1 The Process Model

The process model this approach is based on is the FORFLOW Process Model [Krehmer et al. 2009]. It consists of about 90 different process steps defined in three levels of detail (see figure 2). The model was developed in the context of the research alliance FORFLOW that consisted of six institutes from mechanical engineering and computer science and twenty affiliated companies. Its applicability was shown by modelling the development processes of different industrial partners with the FORFLOW Process Model. To apply the process model to a development task a tailoring of the generic model is necessary. The order of process steps in the first and second level of detail is predefined; the order of steps in the third level of detail has to be defined according to the development task at hand. This is illustrated in figure 2 by the different blocks representing the process steps.

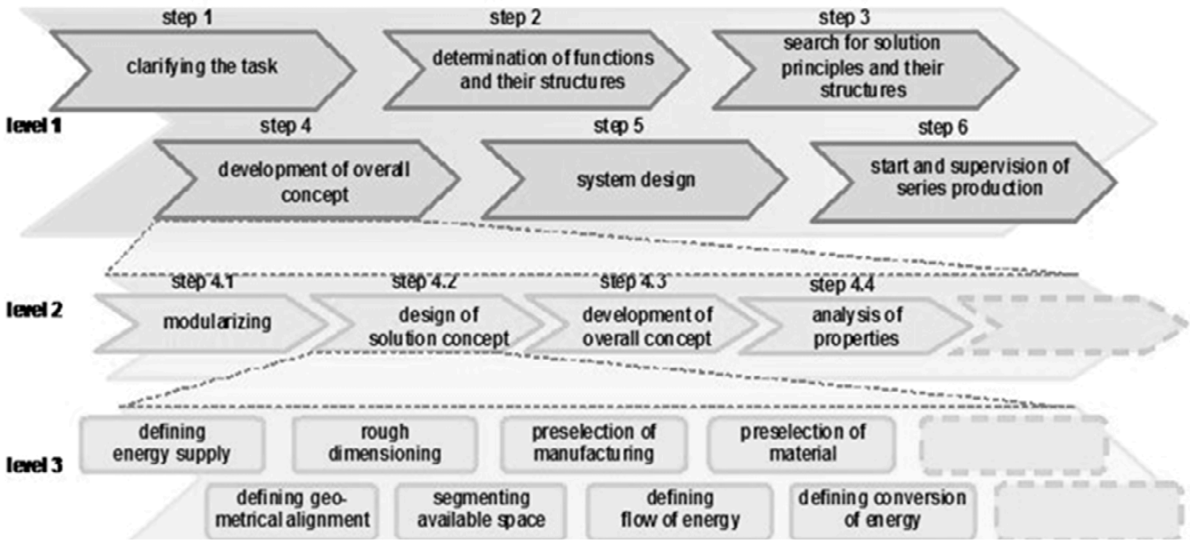

Figure 2. The three levels of detail of the FORFLOW Process Model

The FORFLOW Process Model was developed to meet important challenges in Product development. To these challenges belong the integration of mechatronic aspects, situation specific process planning, the integration of design iterations as well as "lessons learned", the support of DfX- and CAx- aspects, a multi level safeguarding of the product and finally the integration of simultaneous and concurrent engineering. The different DfX-aspects supported include amongst others the lifecycle phases manufacturing, use and disposal of the product. These are mainly regarded in the steps that ensure product validation, e.g. in supporting the choice of the best concept and validation of detailed component design.

As this contribution focuses on situation specific process planning please refer to [Krehmer et al. 2009] for further information concerning the other aspects of the FORFLOW process model. The practicability of the FORFLOW Process Model was shown by a comparison to different development processes that were analysed at the companies affiliated with the research alliance FORFLOW. Their respective development processes could be reproduced using tailored versions of the FORFLOW Process Model.

4.2 Levels of Process Planning

In order to achieve the goals in product development concerning time, cost and quality it is necessary to look at the right level of process decomposition for the right task. According to [Lindemann 2007] there are four levels of decomposition and their respective process models (see figure 3):

- strategic process level (with only generic processes and roadmaps respectively)
- project level (with rough stages but a clear vision of outcome)
- operational level (with interrelated activities but vague certainty of final outcome)
- action level (with elementary processes)

The FORFLOW Process Model supports tailoring for planning design processes on the project as well as the operational level [Roelofsen et al. 2007], as these are the levels of decomposition represented in the model. The actual tailoring of the process model is done according to the design situation as described in chapter 4.4.

The FORFLOW Process Model differentiates between three classes of process steps, according to their necessity in design processes. First, 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 product parts. These are the "MUST"-steps. Second, there are process steps that are highly recommended but not absolutely essential as for example working out a functional model of the product. These are the "SHOULD"-steps. And third there are process steps that can be carried out but are of less interest in some cases, e.g. the abstraction

of the development task, which are the "CAN"-steps. The framework provides support to project planning in the selection and arrangement of the process steps in the first and second level of detail.
Furthermore the process model provides the possibility to arrange the process steps of the third level of detail according to the development task. In contrast to the first levels, the third level of detail has no predefined order of process steps given or recommended in general, but the order has to be defined for each task. This implies that the order of process steps is different for different parts and sub-assemblies of the product developed. Thus the process model can be applied recursively in a development project for the whole system, partial systems and single parts of the product. The support in arranging the process steps of the third level of the model according to the design situation is illustrated in chapter 4.4.

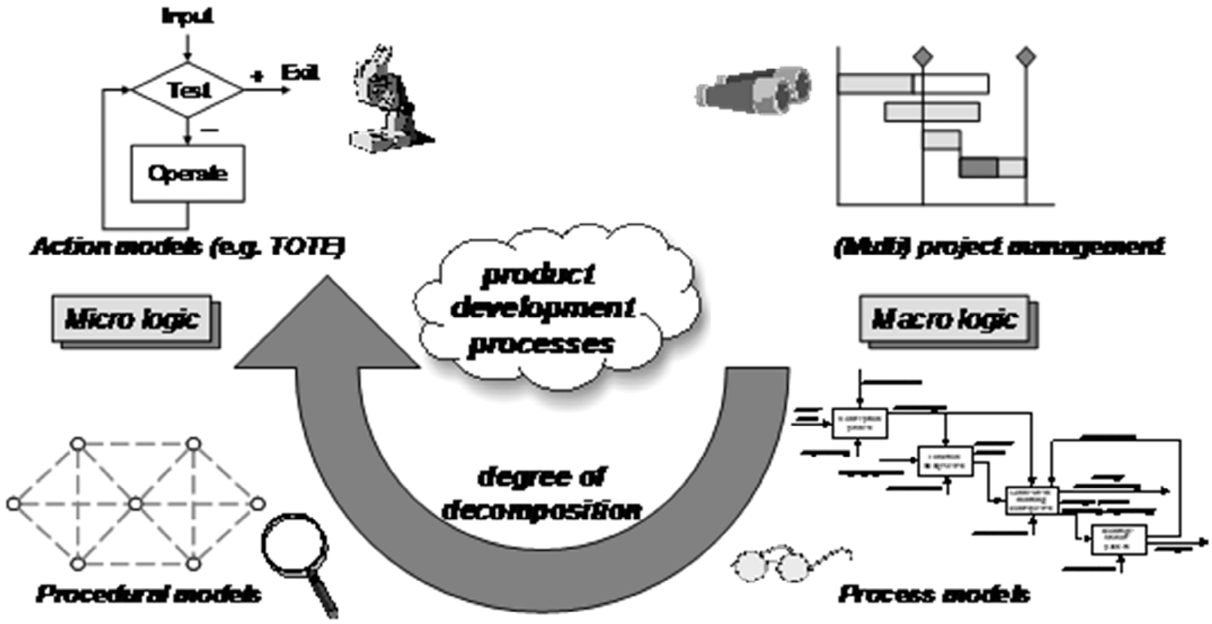

Figure 3. Design process models on different levels of decomposition adapted from [Lindemann 2007]

4.3 Different Roles in Process Planning

The approach presented here deals with two different roles in process planning. These roles are not directly connected to persons or to a project organisation, in which more levels of hierarchy and a larger number of different roles can occur [Kerzner 2006]. Instead, the differentiation between project planning and operational planning is sufficient to perform the kind of process planning presented here (see [Roelofsen et al. 2007]). This splitting of the process planning in two roles makes the framework applicable for many different situations. It does not matter whether there is one project manager, who builds a project plan at the beginning of a project, or whether there is a group consisting of people from the different domains involved in a development project that create the project plan in collaboration. The same applies on the operational level. Here, a working group can plan their specific tasks in order to develop e.g. a sub-assembly, or a single engineer can plan and adapt the development of the product part he/she is responsible for. Finally for small projects it is possible that both roles are fulfilled by the same person, first planning the overall task and afterwards planning the single steps in more detail.

4.4 Design Situation

The design situation is an important part of the framework for situation specific process planning. In literature there are many different approaches that describe the design situation concerning different objectives (e.g. [Hales and Gooch 2004], [Badke-Schaub and Frankenberger 2004]) that illustrate the importance of the situational influence on engineering work. As these descriptions of the design situation are either very extensive or have a different focus, an applicable description of the design situation was developed. The situation description was developed based on literature research and discussions with the industrial partners of the research alliance FORFLOW. These had mayor influence on the selection of the parameters applied for situation analysis. Figure 4 shows the interaction between the design situation and the product development process.

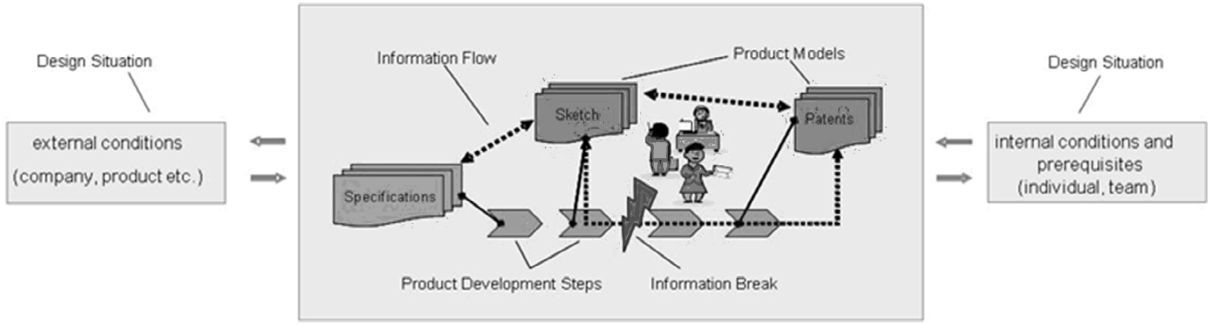

Figure 4. Interaction of the design situation and the development process

The situation description applied in this contribution takes into account the different levels of process planning. That means that different parameters are used to describe the situation on the two levels.

The interaction between these levels of planning, i.e. providing the possibility to switch between both levels of detail while planning, is essential in order to gain a high value of information and transparency of the process plans. It puts emphasis on the necessity to communicate between the roles of project planning and operational planning. To achieve a context description that is feasible for process planning, the approach focuses on factors that can be measured or at least estimated at the beginning of a process. Some of the parameters are only relevant for one of these levels of decomposition while others apply for both levels but regard different aspects. Furthermore parameters have to be considered without taking a specific level of process detail into account. [Roelofsen et al. 2007] The general parameters for the situation description (chosen in this approach) are:

- Design problem and requirements
- Process results (i.e. the required outputs)
- Degree of novelty
- Complexity of the task.

The situation-describing parameters that are considered on the project level are:

- Customer
- Risk
- Project constraints
- Structure of the design problem
- Number of units produced

On the operational level the influencing factors regarded are:

- Product models available/process up to the present point (Input)
- Required output/planned succeeding process steps
- Structure of partial design problem
- Operational constraints (organisational, individual, environmental prerequisites)
- Interdependency with other process participants (number of interfaces) [Roelofsen et al. 2007]

As mentioned before, these parameters were chosen in dialogue with industrial partners. Other possible parameters as e.g. project strategies or a company´s functional strategy (for instance distribution, re-use, and disposal) are not regarded here, as they are difficult to measure or to assign values to them respectively and thus are inapplicable in this case. But the overall method of process planning is adaptive so that if a company wants to use these parameters and has a way to assign values to the different strategies respectively, these situation describing parameters could be included in the situation analysis.

The description of the design situation on project level is used to recommend the different process steps to the person carrying out the role “process planning”. For example for a high risk project different steps will be recommended than for a low risk project. To these extra steps, which are recommended for high risk projects, belong amongst others the creation of a functional model of the product. Another example is the number of units produced. If only one unit is produced, the use of hardware prototypes will not be recommended for the whole system, whereas it is recommended for mass production.

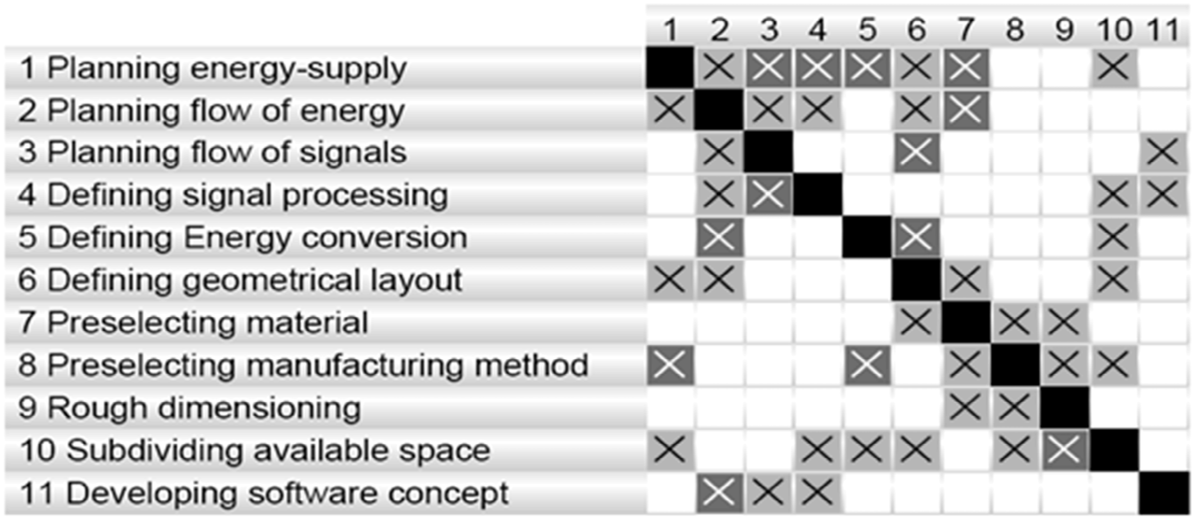

Figure 5. DSM of the process steps of the third level of detail [Roelofsen et al. 2008a]

The recommendation of process steps on the operational level works differently. Here, the order of process steps is not predefined, so beside the selection of the steps also their arrangement is important. The analysis of the design situation first helps to choose which steps to carry out. The recommendation for the order of process steps is derived from the analysis of a Dependency Structure Matrix (DSM) of the process steps (see figure 5). The DSM is filled according to the analysis of the design situation, that means the dependencies between the process steps change according to the given design situation, which is displayed in the DSM. The DSM is then analysed and from this analysis the recommended process order on third level of detail of the process model is derived. For further information concerning the analysis of the DSM see [Roelofsen et al. 2008a].

4.5 The Procedural Model

The procedural model used for the framework for situation specific process planning bases on the Product Model Driven Development (PMDD) approach introduced by [Roelofsen et al. 2008b]. The procedural model introduced then was complemented on the project level by a “Project Process Plan” and the “Project Targets” as can be seen in figure 6.

In this model, product development starts with a request by an internal or external customer. This request initiates a project. On the project level, the strategic decision has to be made whether the request shall be accepted or not. Before the work at the actual product can be started on the operational level, project planning has to fulfil some tasks. First, the project situation has to be analysed in order to recommend process steps and afterwards do the tailoring of the process model for the first and second level of decomposition. The result is thus the overall “Project Process Plan” that is the referential overall plan throughout the project. This plan is only adapted if there occur major changes in the design situation on project level. Otherwise, the project plan and the project targets derived from this plan as well as the customer request are necessary to keep the overall project goals in mind and are used to check the fulfilment of targets during the project. As the procedural model is applied recursively many times during the design process, the overall project plan and project targets are checked concerning their fulfilment regularly during the design process.

The first step on the operational level is the analysis, which product models are available. Product models in this case are all artefacts that carry information concerning the product to be developed (e.g. requirements, sketches, CAD-models, project targets). After the first customer request these can be documents provided by the customer (product specification or request for quotation) or the aforementioned project targets, in later project phases product models can be e.g. sketches, CAD-data, prototypes and so on. The information about product models available is one of the main inputs for the situation analysis on the operational level. As described above, according to the situation analysis, recommendations for the order of process steps are provided. Process planning on the operational level takes into account the required outputs of the following process steps as well.
After planning the order of process steps, the process is executed. After finishing the current process step, the results are matched with the project goals. A project is completed, if the product models generated in the current process step correspond to the ones defined as the project goals. As long as the models do not match, new operational process steps have to be started. This loop implements the connection between the project and the operational level. Moreover this allows the recursive application of the procedural model for different sub-systems and product parts.

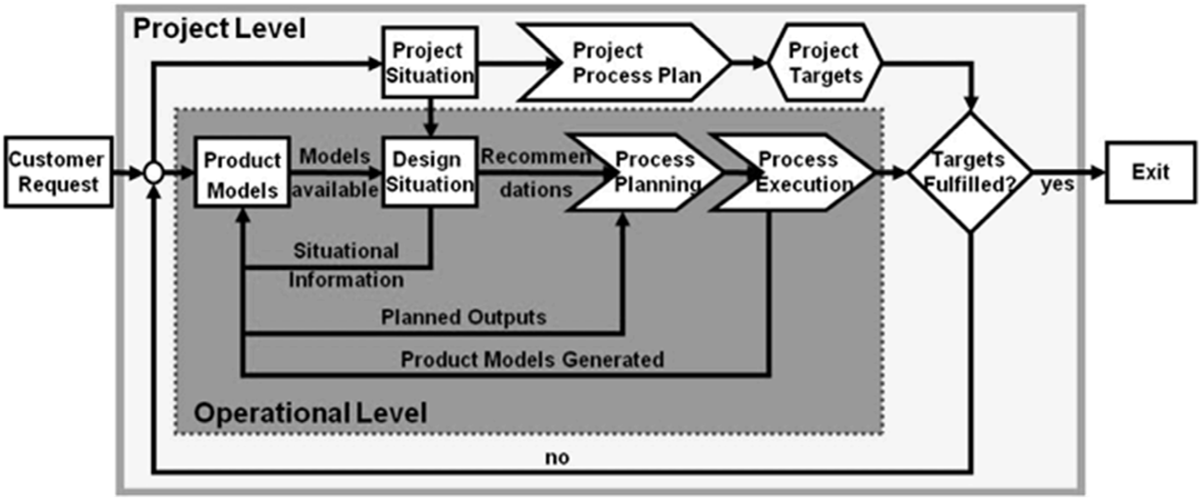

Figure 6. Procedural model of the framework

The focus on product models as the main (intermediate) results of development processes is expected to facilitate a development workflow, because it improves process transparency. This is achieved by providing an overview of the product models available and taking into consideration the design situation for every new process step. The link between project and operational level helps to keep the overall project goals in mind for the next process steps (see [Roelofsen et al. 2008b] for further information).

4.6 The Framework

The framework builds the connection between the different aspects discussed above. It establishes the relation between the FORFLOW Process Model, the procedural model PMDD and the analysis of the design situation. The framework is implemented in the so-called Process Navigator that integrates the main results of the research alliance FORFLOW. The Process Navigator supports engineers in many different aspects of their daily work, as e.g. searching for specific documents, supporting the exchange of different types of CAx-data, connecting the design process and product models etc. [Meerkamm et al. 2009]. In the paper at hand, the emphasis is put on the part that deals with the support of process planning. The Process Navigator enables the management of design processes and the definition of a flexible workflow that is applicable in product development [Lauer et al. 2008].
At the beginning of a development project, the person responsible for project planning starts a project and defines the rough process by choosing and arranging the relevant process steps, defining the milestones and setting the important dates. For the execution of the process different roles are defined, that have to carry out the respective process steps.

On the operational level, there are thus two different views of the process. One view shows the steps assigned to a specific role, the other view shows all process steps assigned to the project. This information is displayed on the left hand side of the Process Navigator screen, according to the view chosen by the user (cp. figure 7). On the right hand side there is a variety of different views that gives project specific information to the engineer. Amongst others there is information supplied about the product models required to carry out a process step and whether these models are available or not, as well as the product models that have to be changed or generated during the respective process step.

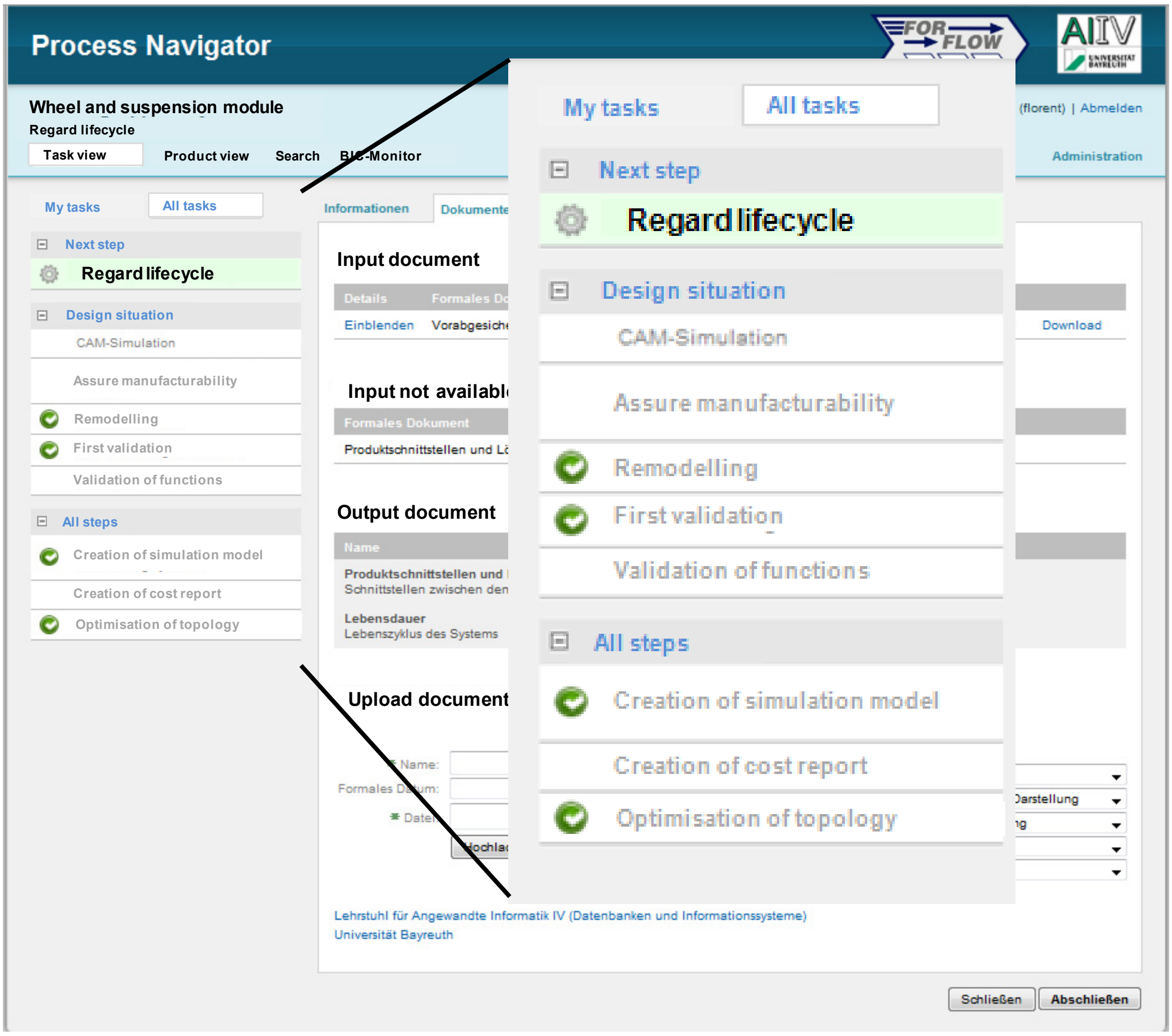

Figure 7. Display of process information for the operational level in the Process Navigator

The flexible process execution is carried out as follows. The process steps assigned to a specific role are displayed to the responsible persons, as well as all process steps can be viewed by all participants.
The process information consists of three parts that are displayed in both views. The first part is the "Next Step" assigned in the planned process order, either for the role or in the general process, depending on the chosen view. The second part is called "Design Situation". In this part, the surrounding process steps of the current one are displayed. The third part shows all process steps (on the first level of detail of the process model). The engineer working on the operational level is free to jump between process steps. That means he does not have to follow strictly the process order that was predefined on the project level but can adapt the process to his needs. The process steps displayed in the "Design Situation" are shown in the order derived from the process DSM and thus the "Design Situation" supports the selection of process steps. The same applies for the display of product models

necessary to perform a certain step. The information about all process steps is given in order to show the importance of the process step at hand for the entire project and to give the opportunity to switch to steps that are farther away (in terms of the order of process steps) from the current task than the ones displayed in the "Design Situation". Thus it is possible to roughly plan the design process on the project level and give enough room and support in process execution on the operational level to enable fast reaction to changes in the design situation. The person working on the operational level gets extensive information concerning the planned process order, interfaces of the steps assigned to his role and other steps as well as the "big picture" of the development project.

4.7 Evaluation

The framework as it is implemented in the Process Navigator was evaluated in two different ways by different groups of industrial practitioners as well as students and researchers. One group consisted of the industrial partners of the research alliance that had the possibility to try the Process Navigator during a workshop and give their feedback. In that workshop about 30 persons used the Process Navigator simultaneously. Moreover there were workshops at five of the industrial partners, where the Navigator was tested in more detail. In addition to that three Formula Student racing teams tested and evaluated the Navigator concerning their needs. This evaluation of the navigator functionalities based on workshop in which the running system was tested by simultaneously carrying out an exemplary project was one of the two evaluation methods. After running the exemplary projects including different roles and assigned tasks, the participants were asked for their feedback regarding the Process Navigator functions. Which did they find helpful, which were unnecessary, were there functions hard to understand or to use, where could the system be improved, which further functions are called for and so on. The second type of evaluation is the use of the Process Navigator in a pilot project at one of the partner companies of the research alliance FORFLOW. As this project is not finished yet, there are no evaluation results that can be discussed here concerning the pilot application in industry at this point.

The general feedback regarding the Process Navigator in the aforementioned workshops was very positive. The different types of support provided for both project planning and operational planning were rated very useful. The biggest obstacle for putting the Process Navigator to industrial use was seen in the compatibility with already existing tools. Due to the knowledge base, in which process and product information is administered data inconsistency e.g. with PDM-systems already in use could occur. Another possible drawback could be the acceptance of yet another software tool by the developing engineers. Thus it is the next task to clearly show the advantages in everyday-work that the engineers can gain by using the Process Navigator, besides the proof of practical applicability that shall be derived from the pilot project at the partner company. In addition to this the application of the process planning methods introduced in this contribution is planned for a students´ project in order to identify potential for further method improvements. The already existing demonstration that the Process Navigator works in small distributed projects as was shown during the evaluation workshops is a promising start for the further evaluation and development of the system. The feedback from the workshops and the pilot project will be used to improve the system functionality.

5. Conclusion and Future Work

The framework for situation specific planning of development processes introduced in this contribution brings together a number of approaches that support situation specific planning of design processes that were developed in one partial project of the research alliance FORFLOW. Combining these approaches in the framework increases their applicability in practice and improves the support that the approaches provide separately. In the Process Navigator the partial approaches displayed in this contribution (the FORFLOW Process Model, Product Model Driven Development, the description of the design situation, the methodical support in choosing and arranging process steps) as well as the framework are implemented. This implementation has been extensively evaluated both in academia and industry, which lead to positive results.

As the framework itself is part of the Process Navigator and was not yet evaluated separately, the evaluation of the framework is still to come. For this purpose, different development projects that are carried out by students will be analysed concerning their process planning. Based on this analysis students will apply the framework for planning a development project. The pilot project carried out at the moment will be used to evaluate the process planning framework presented here.

Acknowledgement

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