INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 03 STOCKHOLM, AUGUST 19-21, 2003

DESCRIBING SOLUTIONS TO THE CONCEPTUAL PHASE – STRUCTURED AND USER-ORIENTED

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Abstract

In order to increase the efficiency of the conceptual phase of the product development process it is necessary to support the designer in structuring his problem solving process. This paper shows a first approach for a model which describes the conceptual phase of the product development process. Based on the experiences with a number of development projects and approaches described in literature, a so-called pyramid-Model will be presented, which is able to describe the successive definition of design characteristics during a development process. The paper closes with an outlook on the implementation of the model in an integrated learning and teaching system for product development.

Keywords: VDI 2221, systematic product development, knowledge-based engineering, experiential learning

1 Introduction

1.1 The early design phase

In the age of globalisation and information technology, flexibility and quick reactions of industrial companies are becoming more important. This leads to shorter Product-Life-Cycles while the product complexity increases. Thus knowledge and innovation are becoming increasingly important factors for companies. In this context different requirements for product development arise and the optimisation of the product development process is a matter of particular interest for companies. The early design phase is especially essential for the success of a company. According to the differences of existing products, the tasks and the problems of a designer are very heterogeneous. In order to deal with them a designer needs on one hand special knowledge about techniques and natural science, and on the other, skills in methodogical problem solving and the systematically structuring of a design task. These skills are of special importance in the early design phase, where the designer has to make decisions which establish the features of the product.

1.2 Methodogical Development in theory

The structured guideline VDI-2221 [1] offers a number of methods for supporting the designer in developing new products. The guideline structures the product-development-process in a sequence of seven steps. Depending on the design task it is necessary to work on individual steps, on all steps or repeat certain steps more than once.

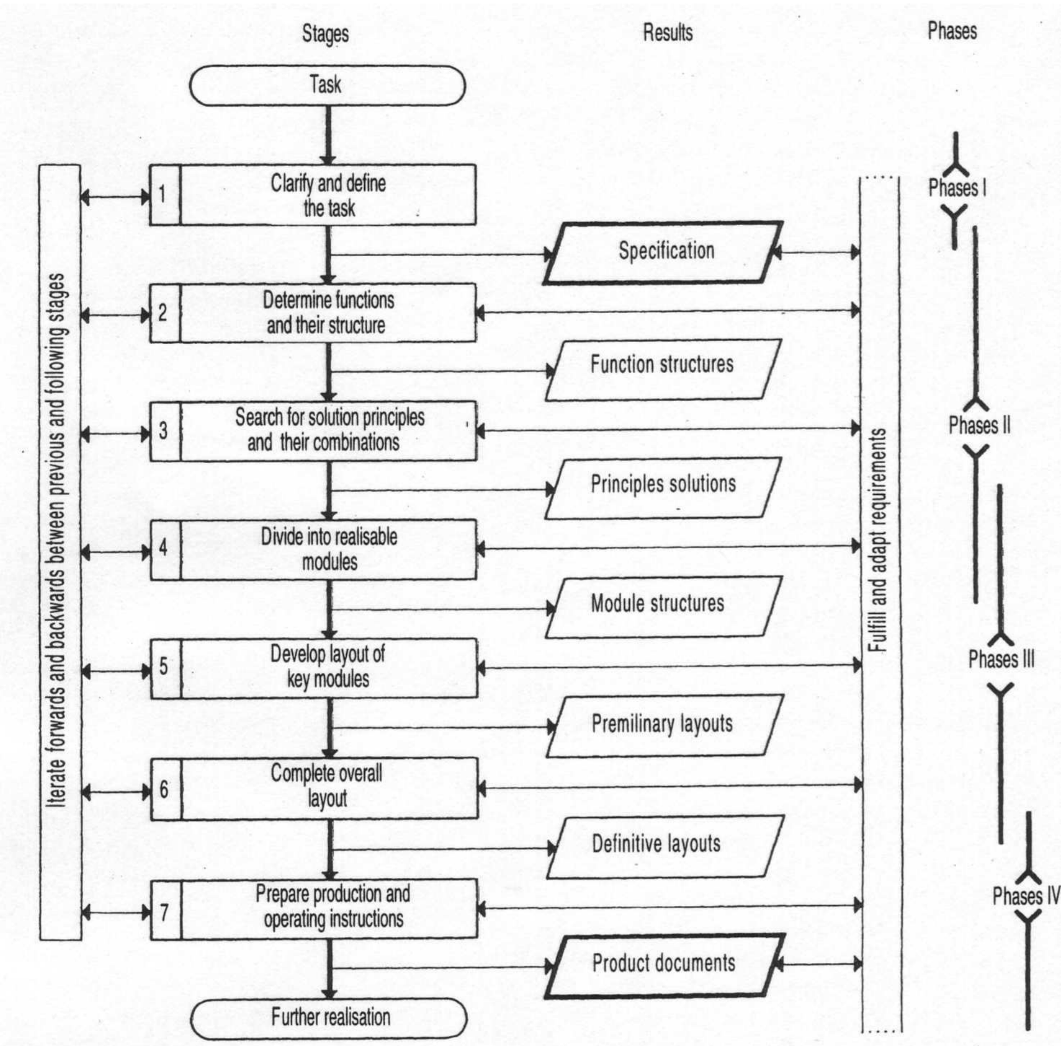

Figure 1 The Structure of product development according to the VDI-2221 [1]

- Step 1 is necessary to clarify the design task and to derive requirements. This step is marked by the collection of a huge amount of information and the identification of information gaps. The result of this step is a structured list of all requirements, which is the basis for the following steps.
- In Step 2 the functions of the product must be defined. Starting with the entire function of the product, all sub functions which the product has to fulfil must be analysed. Results are one or more function-structures, giving an overview about the functions and their internal, logical connections.
- Step 3 involves searching for solutions for important sub-functions. The solutions for the different sub-functions must be combined into overall solutions, the result of that step.
- In Step 4 the overall-solutions are structured into realisable modules. The modules have to be made concrete by adding information about materials, geometry, etc..
- Steps 5-7 arrange the very high expenditure phase of embodiment of the product into several Steps.

A characteristic of all the steps is that several solutions are generated, analysed and evaluated at the same time. The decision for one solution is based on the collected and documented information of the design process. The solutions of the conceptual phase are normally stored in the designer's brain because data-management is not widely distributed in that phase. These solutions are lost for later projects.

In order to increase the effectiveness of methodogical development according to the VDI-2221 and to enable the re-use of solutions, the guideline aims to integrate data management into the development process. Therefore a model which describes all the results of the conceptual phase and the successive definition is necessary.

1.3 Methodogical Development in Practice

The knowledge of the guideline VDI-2221 is wide-spread in industry and described in very well known references like [2]. But several empirical investigations [3] point out that systematical development according to the VDI-2221 is not very widely distributed in industry. In practice, often a mix of intuitive and experience-based behaviour can be found. To understand why designers in industry do not often use methods, a more detailed look at their situation is necessary [4]. Design work in industry is marked by a lot of restrictions, e.g. lack of resources and high time pressure. Thus designers are interested in key-turn-tools, which are ready to use immediately. They want to apply the methods directly in their daily work in a problem-oriented way.

Due to the restrictions of design work in practice, step-oriented development according to the VDI-2221 seems to be fixed and inflexible for designers. In addition, especially young, non-experienced designers often fail in selecting and effectively using methods. In literature the methods are often described in several ways, which complicates their use even more.

2 Deficits

Important for an efficient product development, is the selection and the situation-adjusted use of methods. Thus the commitment to a starting point of the development project and the specification of the objectives are of special importance. In this case the phase-oriented description of the product development process (VDI-2221) is not suitable, because real product development projects often do not run through all steps from the task clarification to the product documentation. Sometimes it is necessary to start with a later step, to skip one or more steps or to jump back to an earlier step. The decision for the sequence of steps is based on the experience of the designer.

The efficiency of the product development process can also be increased by the integration of databases with solutions. These solutions could be, for example, product concepts of completed projects or collections of standard principles, like the construction catalogues of Roth [5]. A problem is the integration of such databases in the development process and the access to suitable solutions. In real product development projects only the results are normally documented, not the method of construction. But this is a prerequisite to evaluating the aptitude of a solution for a concrete task in another project.

3 A holistic approach

The special situation described above obviously needs a holistic approach to improve the methodogical development. This approach is aimed at eliminating deficits concerning the surroundings of the designer, the designer himself, the availability and quality of design knowledge, supporting tools and a sustainable transfer.

Such a holistic approach was generated within the "pinngate"-project in the pmd-department at Darmstadt which is a follow-up project of the thekey-project [6]. The main objective of pinngate is to build up a system which supports the learning and teaching of design methods, but which is also ready to use in solving concrete design tasks. Flexibility, individuality, adaptability and up-to-date information are the main characteristics of the pinngate-system.

To achieve this, the designer is placed in the centre of this approach. All the improvements are intent on adapting to the individual situation, the special background education and the specific task of the designer. Thus the pinngate-system is characterised by three sub-systems:

- Knowledge-bases, where the theory of product development, design methods and concrete solutions described according to an integrated product-model are provided [7].
- Learning and teaching environments presenting learning documents which consider the different requirements of special target groups [7].
- Design method tools which are ready to use supporting the designer working on concrete design tasks [8].

All these sub-systems are connected in order to use synergy-effects. The module “concrete solutions” of the knowledge base contains all the information the designer needs to solve his design task. This information is the basis for tools the designer uses to find and evaluate solutions. But even more, the contents represent the knowledge generated during concrete developing projects.

4 The role of product-models

To understand the importance of product-models for the design process, a closer look at the development process is necessary. Product development can be conceived as step-by-step problem solving over several sub-results. By every step, the designer has to make decisions about the product (properties) and the development-process.

During the product development process the designer has to make decisions, regarding not only the respective product features but also the development process itself (e.g. the decision for the use of a special method). For these decisions, knowledge is necessary. Because the designer develops a product step-by-step, he/she has to make decisions on different concrete levels. From this point of view, designing can be conceived as a successive definition of a product idea through decisions on each level [9].

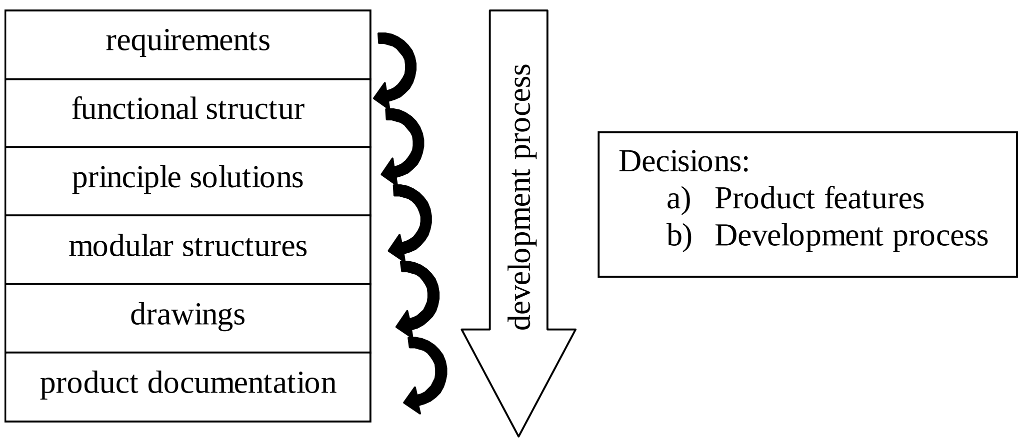

Figure 2 Step-by-step product development

To overcome the deficits of the VDI-2221 described above, it is necessary to set the product in the centre of the product-development process. The engineer’s objective is to solve a design task by developing a product which fulfils the derived requirements. Step-by-step the engineer realises the product from a given task to the final product-documentation over several steps.

The key to increasing the efficiency of product development is to generate a model which demonstrates the successive definition of the product and shows the information links between the different levels.

5 The Pyramid-Model

5.1 The Model-Structure

Based on an analysis of several development projects, an approach for a product model in the shape of a pyramid is generated. It considers the problem solving process and the sequence of product development steps. The approach bases on the description of the product development process of Andreasen [10].

The levels of the pyramid typify the successive definition of "design characteristics". Thus the complexity of the description of the product increases along with the number of alternative solutions (Fig. 3). That's the reason why the pyramid must run from the top to the base.

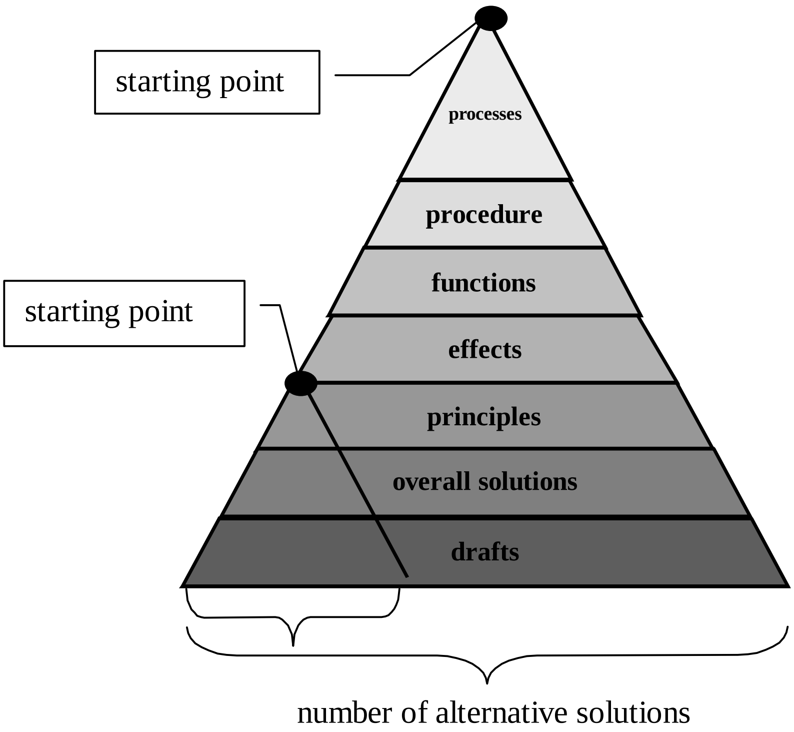

Figure 3 The product-Model-Pyramid

The starting point of a project may be an open problem or it may lie somewhere down in the pyramid. In practice that definition often causes problems because there is no model which describes the different levels and the design degrees exactly. Even more, the design problem is often not one defined task, because products are complex and different sub-tasks arise. These sub-tasks may define different starting points. So the first question the designer has to answer is: "How far up the pyramid do we go?" [10]. According to this it is not always necessary to go through all the levels of the pyramid.

- In „new design“-projects, the formulation of the task is open. The project starts with an intensive task clarification and the definition of processes which the product has to fulfil since the technical functions are not known in advance. In this case the projects starts at the top of the pyramid and the designer has all the “design degrees of freedom” [10].
- Quite often the starting point is already more concretely fixed. In this case the designer starts on a sub-level of the pyramid with fewer “design degrees of freedom” but also with fewer risks than in a “new design”-project.

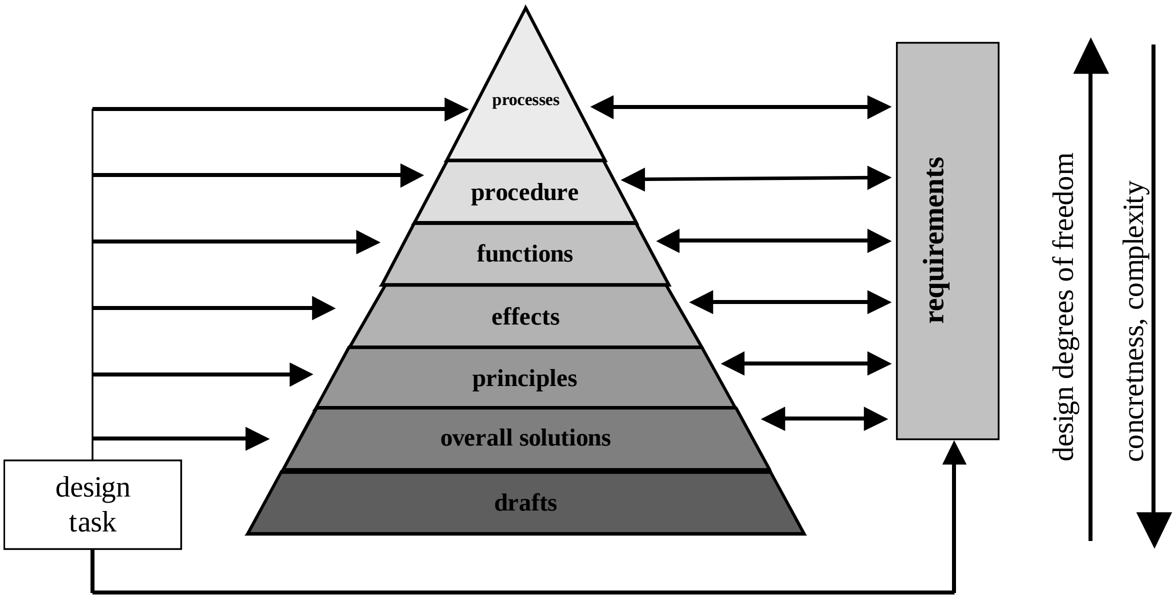

Figure 4 The structure of development projects

Similar to the VDI-2221 several alternative solutions have to be generated, analysed and evaluated on each level. Especially for the evaluation steps, requirements are necessary for decision making. These requirements can be derived from the design task but also from each level during the development process (Fig. 4).

The next sequence will give a more detailed look at the structure and the different levels of the pyramid.

5.2 The structure and the Part-Models in detail

To describe the structure of the pyramid and to explain its different levels, an idealised project is supposed. It starts with an open problem at the top of the pyramid. The first step is the definition of the processes. The description of processes is based on the distinction of the purpose and the method of a product [11]. Every product fulfils a purpose. This purpose is normally to transfer an object from one state to another. This transfer is a process. The process description reduces the product to a sequence of processes, thus making it easier to recognize the core of a design problem and to derive important requirements.

The description of the procedures follows on level two. Every process can be realised by several procedures. The fixing of usable procedures means a pre-structuring of the field of possible solutions. Technical products realise procedures by providing an activating force through transferring a given input into that activating force as an output. This transfer is called the functional description of technical products [5]. With the functional description the designer gets to the core of the design task.

After this step the first phase of the product development process is finished. The design task is analysed, the purpose of the product is defined and the requirements are derived. With the definition of suitable procedures, the field of solutions is structured and enclosed. The functions present the core-tasks for the development. For these functions solutions will be systematically searched in the next phase.

The second phase is marked by the search for solutions for the defined functions. It starts with the definition of physical effects. An effect is the course of physical events which can be described by laws. In the next step the embodiment of the physical effects is followed by the definition of geometrical and kinematical features.

Analyses of development processes show that the search for solutions often starts with the drawing of principles. In a second step the physical effects are analysed and varied in order to find new solutions. This example shows, that the different levels need not be run through in an hieratical manner. Sometimes it is better to skip a level and jump back later.

The search for solutions by defining suitable physical effects and drawing principles takes place for each function defined in phase one of the development process. In the next step overall solutions will be generated by combining solutions for each function. The overall solutions must be put in concrete order to evaluate them, before the development process turns into the next phase, the embodiment of the favourite overall solution [2].

In phase three the overall solution must be structured in realisable modules to structure the embodiment. The paper does not focus on that phase, even though it is a very important phase.

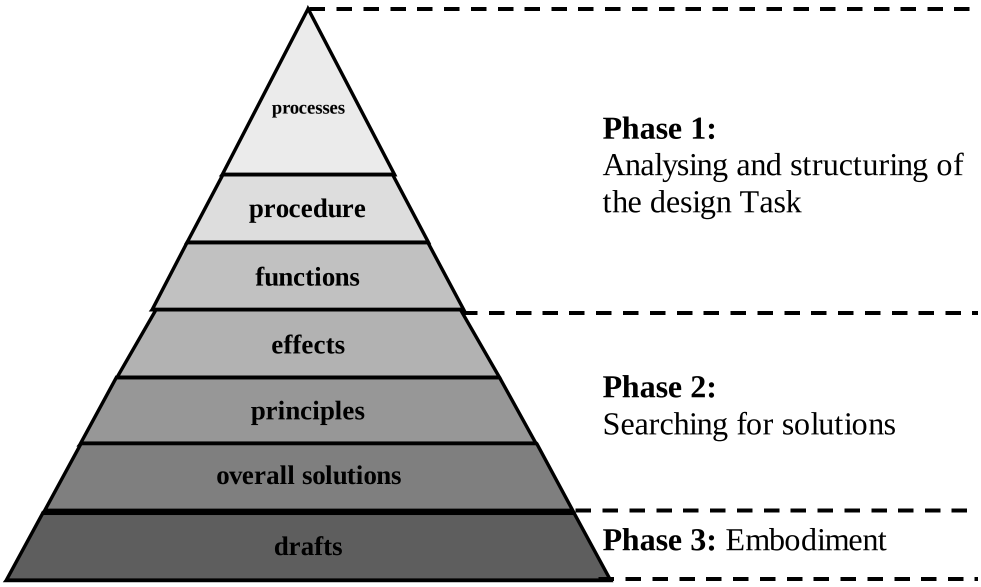

Figure 5 The main structure of the Pyramid-Model

6 Working with the Pyramid-Model

The development of the pyramid model described above is based on the experiences of a high number of co-operation projects between industry and the department pmd [12], on the experiences in teaching product development in industry and at the university, and on the synthesis of several approaches descried in literature. In the next step it must be proven that the pyramid-model helps to structure the development process and promotes the re-use of solutions of former projects.

A prerequisite for this is a structured documentation of the development process and the generated results. But an empirical investigation shows that especially the results of the concept phase are documented in an unstructured way with standard office software (e.g. MW Word®, Corel Draw®). It is difficult to re-use these documents in other projects, because a designer cannot access them. Therefore criteria which describe the documents are necessary. However, due to the limitations of real development projects described above, it is not possible to force a designer to work in a fixed system.

An approach to dealing with that problem is to develop a documenting system for the concept phase on the basis of a full text database (e.g. AskSam®). This system integrates the standard office data formats. In addition it is possible to add structured data fields to the document. With this system, templates can be generated according to the pyramid-model: for each level a special template exists. On one hand the designer has a structured guideline through the concept phase since the templates are based on the hierarchical levels of the pyramid-model. On the other hand the designer produces semi-structured documents which can be stored in a database and used for other design tasks.

7 Results and outlook

The Pyramid-Model shows an approach to overcoming the deficits of a phase-oriented description of the development process. It shows the successive definition of a product during the conceptual design phase. The experiences with the Pyramid-Model in development projects show that it is helpful for a designer in defining the starting point of a project and in planning the steps. But the pyramid is not only a kind of description-model of the development process. It is also an approach to integrating several (part-)models described in literature e.g. [13].

The paper only shows the first ideas. Up to now the paper describes only the conceptual phase, but it could be extended to the drafting phase. In practice a gap between the conceptual phase and the drafting phase could be recognised. In the conceptual phase computer-tools and data-management are not very distributed. Solutions are often stored in the brain of the designer only and so they are lost for later projects. In the drafting phase CAD- and PDM-Systems are state-of-the-art. The designer completes a parametric model and stores it in a database. The model may close this gap by describing the results and their successive definition in all phases.

8 Literature

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