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PROVIDING EXAMPLES FOR STUDENTS AND DESIGNERS

T. Sauer

University of Technology
Darmstadt
Product Development and
Machine Elements
Magdalenenstraße 4
64289 Darmstadt
Germany
E-mail: sauer@pmd.tu-darmstadt.de

M. Wäldele

University of Technology
Darmstadt
Product Development and
Machine Elements
Magdalenenstraße 4
64289 Darmstadt
Germany
E-mail: sauer@pmd.tu-darmstadt.de

H. Birkhofer

University of Technology
Darmstadt
Product Development and
Machine Elements
Magdalenenstraße 4
64289 Darmstadt
Germany
E-mail: birkhofer@pmd.tu-darmstadt.de

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Abstract

Methodological development involves a range of different design methods which aim at supporting designers in finding solutions to a given task. Some of them focus on the mapping of given requirements or product properties a customer is looking for onto realizable technical systems. This paper presents and discusses some of these methods. Potentialities of these methods are pointed out and an approach to support engineers in the field of product development –the pinngate-project– is shown.

1 Introduction

In the age of information technology, knowledge and innovation are becoming increasingly important factors for companies [Gausemeier97]. In this context, different requirements for product development arise and the optimization of the product development process is a matter of particular interest for companies.

The early design phase is especially essential to the success of a company. According to the differences of existing products, the tasks 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 methodological problem solving and the systematical 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.

1.1 The pinngate Project

To support engineers in the field of product development, a holistic approach is necessary, which considers all the influential factors. Such an approach is generated within the pinngate-project[1] at the pmd department at the Darmstadt University of Technology. This approach is

[1] www.pinngate.de

aimed at eliminating deficits concerning the availability of design knowledge, the support of method tools and a sustainable transfer of design methods. [Sauer et al.03], [Birkhofer et al.02].

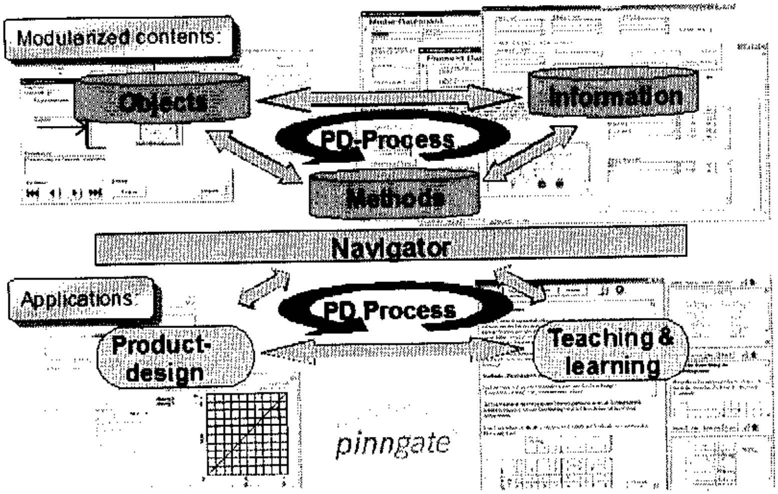

Figure 1: The pinngate-project

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 [Berger et al.02].
- Learning and teaching environments presenting learning documents which consider the different requirements of special target groups [Berger et al.02].
- Design method tools which are ready to use supporting the designer working on concrete design tasks [Sauer et al.03].

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.

1.2 Objectives

The paper focuses on the first part of the pinngate-system (Figure 1: The pinngate-project), the availability and quality of design knowledge (modularized contents), especially the solution-based knowledge (objects).

As described above, the aims of support for product development should be to aid both educations in product development and the daily work of product developers.

2 Providing examples for students and designers

The first objective is to provide learning documents for students and designers. These documents shall contain "real-life"-examples. The examples can be derived from the contents of the "objects-module". In combination with the "information-module" of the pinngate system (Figure 1: The pinngate-project), the teaching and learning documents can be derived from the contents of the "pinngate" knowledge-pool. Therefore a "configurator" – e.g. a teacher who wants to generate documents for an engineering-design lecture – arranges single content-parts up to a document for one or several themes (figure 2: Deriving learning documents from the "pinngate"-system).

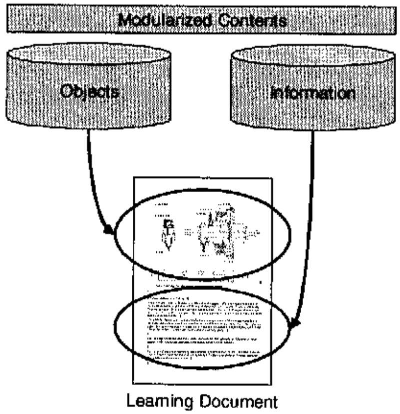

figure 2: Deriving learning documents from the "pinngate"-system

3 Providing solutions for designers

The second objective of this part of the project is to support the designer in generating new solutions. In addition to experience-based and intuitive approaches towards generating new solutions, the systematic variation [Pahl and Beitz97] is a suitable method to create a number of alternative solutions. The systematic variation can be conceived of as the specification of product properties to fulfil defined requirements [Birkhofer80]. In principle, the systematic variation can be used at each stage of the product development process, but a prerequisite is knowledge about the properties which can be varied and the action-related dependence between the properties. The designer has to know which properties are "design parameters" and how the definition of these parameters interacts with other properties.

The paper presents a model which uses a property-based description of technical systems to build up a database with reusable basic solutions in the conceptual phase.

3.1 Background - the guideline VDI-2221

The structured guideline VDI-2221 [VDI-2221] 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.

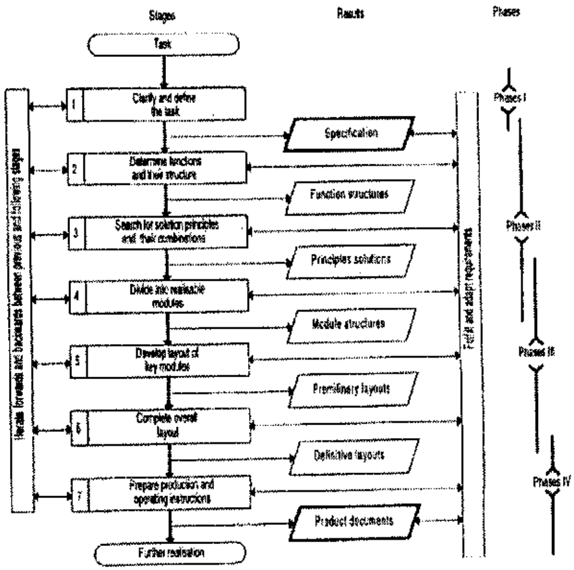

Figure 3: Product development according to the VDI-2221

A common characteristic of all the steps is that several solutions are generated, analyzed and evaluated at the same time. The decision for one solution is based on the collected and documented information of the design process. But 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. Thus, developing new products especially in the early stages need experiences, but also methods, which support the designer in analyzing the design task and finding approaches to new solutions.

The guideline VDI 2221 describes a process which is very complex in practice. It offers a number of methods and strategies for supporting the designer in developing new products.

The focus of the guideline is the process, which is structured in a sequence of seven steps. All the decisions and sub-results during the design process are defined. Based on a design task, the designer derives requirements and defines processes or functions, which the product has to fulfil. These definitions generate the solutions space on an abstract level. Based on his/her level of experience, the designer tries to find a number of approaches suitable to solve his/her design task.

A characteristic of the search for solutions is that several solutions are generated, analysed and evaluated at the same time. First, the designer generates several solutions on a defined level. Then he/she identifies the most promising solution. Especially for that evaluation step, requirements are necessary for decision making. These requirements can be derived from the design task, but also from each level of the development process (Figure 4: The structure of development projects).

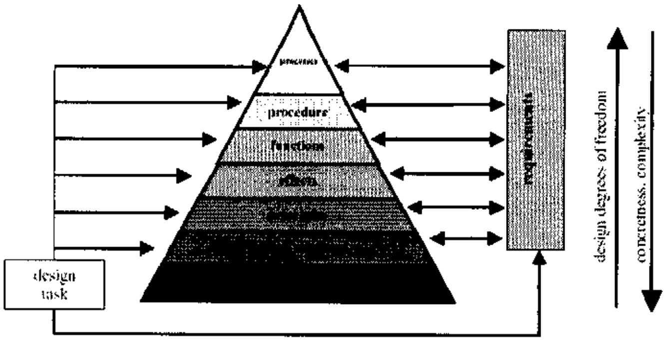

Figure 4: The structure of development projects [Sauer et al.03]

Finding solutions requires experience and creativity, but the knowledge of methods that help to generate and evaluate technical systems is of special importance. The next section will give a more detailed look at some of these methods.

4 Methods and Tools to find solutions

Methods to find solutions can be divided into intuitive and in discursive methods. Intuitive methods are the well-known creativity techniques, such as brainstorming. Discursive methods structure the search for solutions in a sequence of steps. A characteristic of discursive methods is that the designer describes the design task in detail. Then he/she searches for solutions to each individual problem of the design task. In a last step, the designer combines all the individual solutions in an overall solution.

Because of the systematic analysis of the design task, it is possible to support the designer with methods to find solutions and with tools which contain standardized basic solutions. In the next section four examples are shown.

4.1 TRIZ

Altshullers *Theory of Inventive Problem Solving (TRIZ)* is a collection of techniques for innovative engineering design. Like brainstorming, TRIZ is an intuitive method. But unlike this technique, TRIZ provides a systematic method for engineering design [Herb et al.00].

In the early 1950's Altshuller began studies of patent collections. He aimed at revealing similarities between engineering problems and solutions resulting in patents. His research produced these basic rules of inventive design:

- Finding an inventive solution means eliminating the contradiction between new requirements and an existing technical system.
- An exact formulated problem is a perquisite to finding innovative solutions.
- Many problems are solved in other domains by similar principles.

Based on these five basic rules, TRIZ consists of four elements: Knowledge, Analogy, Vision, and Systematic. For this paper, the knowledge-component is of special importance.

Frequently, when searching for inventive solutions, there is a need to use physical knowledge unknown to the domain engineer. Thus, to support the designer with the appropriate physical knowledge, TRIZ consists of a database with physical phenomena. The phenomena are structured according to technical functions and not – as is common – to engineering domains [Herb et al.00]. Based on a functions analysis the designer identifies the functions the technical system has to fulfil. The TRIZ-Database helps to find suitable physical effects which realize these functions.

As an intuitive method TRIZ helps to find ideas and approaches to new solutions on an abstract level. These ideas must be realized step-by-step during a design process which is not supported by TRIZ.

4.2 Systematic Study of physical processes

If the solution of a problem involves a known physical effect, various solutions can be derived from the analysis of the relationships of the physical variables. Another way of obtaining new solutions by the analysis of physical equations is the resolution of known physical effects into their individual components. Rodenacker has given several examples of this procedure [Rodenacker91].

4.3 Design Catalogues

An important and well-known tool to support the designer with structured knowledge about effects and principles is the design catalogue of Roth [Roth82]. The core of design catalogues is the realization that most of the technical solutions are based on a limited number of basic principles. And these principles realize specific technical functions by a limited number of effects. Such basic effects and principles are collected in different design catalogues.

Each design catalogue has a standardized structure (e.g. Figure 5: design catalogue with mechanical gears). Characteristic is the access-part of the design catalogue. This part helps to find suitable solutions and to separate them from the unsuitable ones. Unfortunately, there are no rules or guidelines to create the access-part of a design catalogue by using a standardized collection of product properties. Thus, the catalogues are heterogeneous and difficult to use.

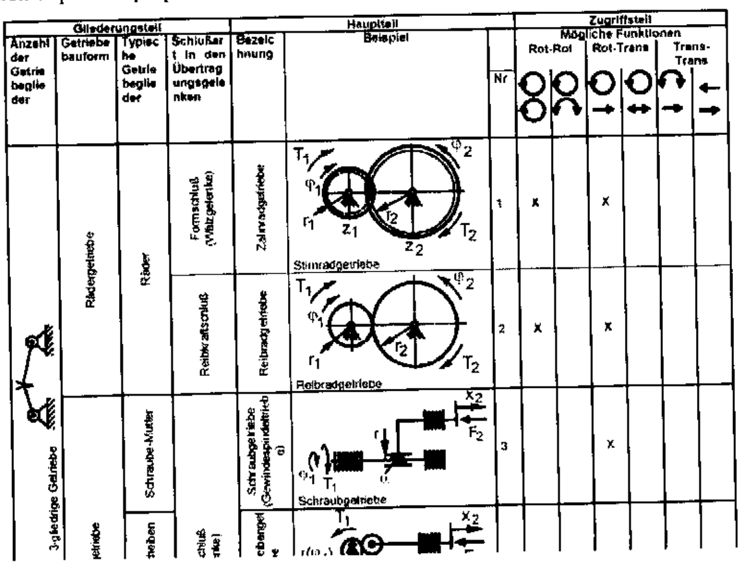

Figure 5: design catalogue with mechanical gears

4.4 Axiomatic Design

Engineering design is based on the interplay between "what we want to achieve" and "how we choose to satisfy the need" [Suh01]. To systemize the process involved in this interplay, Suh has crated the concept of domains which is the basis for axiomatic design. Engineering design is made up of four domains: the customer domain, the functional domain, the physical domain and the process domain (Figure 6: Domains of the design world [Suh01]).

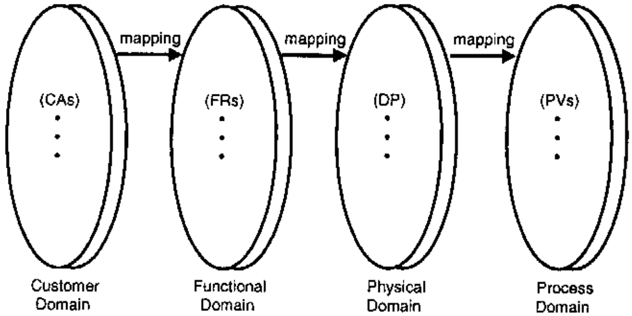

Figure 6: Domains of the design world [Suh01]

The customer domain is characterized by attributes the customer is looking for in a product. In the functional domain the customers' needs are specified in terms of functional requirements (FRs) and constraints (Cs). To satisfy these functional requirements, the designer conceives design parameters (DPs) in the physical domain. Finally, in order to produce the product specified in the terms of design parameter, the designer develops a process in the process domain.

4.5 A sobering summary

To develop innovative products, it is necessary to evaluate the attributes the product will have as early in the design process as possible. A survey of Grabowski [Grabowski97] points out the importance of the identification and observation of product attributes during the design process. Grabowski mentions several measures to improve the identification and observation of product attributes during the early stages of design:

- Supporting the observation of product attributes in the early stages by suitable design methods.
- Systematically structured basic solutions to support the identification of product attributes.

The methods discussed in the last section support the designer more or less in identifying and observing product attributes during the design process.

TRIZ is based on a systematic problem-analysis. The designer identifies (functional-) product-attributes. With these attributes the designer has access to physical effects in a database. But TRIZ supports the designer only on an abstract level. Methods to observe product attributes on more concrete levels are not available. Also, the database consists only of effects and principles on an abstract level. The systematic study of physical processes of Rodenacker [Rodenacker91] functions on a more concrete level. If the physical effect is known his approach helps to derive solutions from the analysis of the physical variables. A problem with this approach is that there are no catalogues available which help to identify the relationships of physical variables.

Such catalogues are the design catalogues of Roth [Roth82]. Roth distinguishes between properties a designer is looking for in a technical product (access-properties) and properties which describe the inner structure of the technical system. Thus, each design catalogue contains an access-part where the access-properties are collected in order to allow for the effective access to the solutions in the design catalogue.

Suh [Suh01] also uses such a differentiation, but he focuses on the interplay between properties a customer wants in a product and properties which can be used by the designer to create new products.

The main deficit of the discussed methods is that they do not support the designer in a holistic way. Some (e.g. Axiomatic design) help to structure the design process and to identify important design parameters. Others provide design knowledge in catalogues (e.g. design catalogues) and databases (e.g. TRIZ). But there is no approach which contains both measures Grabowski [Grabowski97] had mentioned.

5 Supporting the designer in finding new solutions

The key to supporting the designer in finding new solutions is to make the distinction between properties which describe the effects of a technical system to its environment (outer-properties) and properties which characterize the inner structure of the technical system.

A designer cannot define an outer-property in a direct way. Each outer property must be led back to inner-properties which define the outer property. The approach to supporting the finding of solutions is based on the analysis of the interplay between inner and outer properties.

Every product is designed with the purpose of processing certain defined properties. Therefore, the requirements represent values of individual properties the product should possess. As mentioned above, the list of requirements should be as complete as possible. Hubka [Hubka and Eder92] attempts to achieve this by working out a full catalogue of properties as an aid for the designer. Therefore, he has defined classes of properties that characterize the technical system. Various relationships exist among the properties (Figure 7: categories of product attributes according to Hubka [Hubka84]).

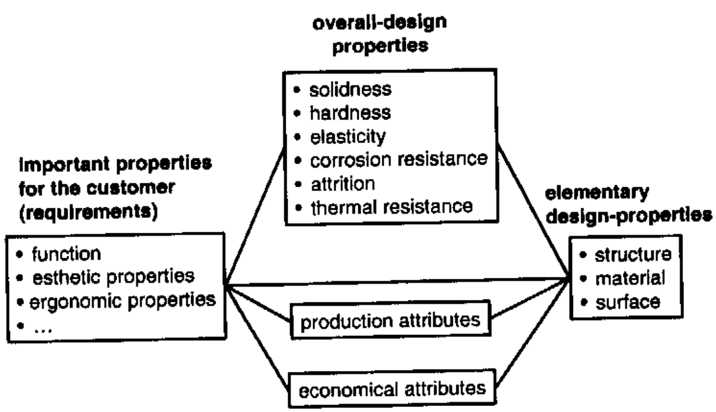

Figure 7: categories of product attributes according to Hubka [Hubka84]

With this categorization a model which describes the properties of basic solutions and the relationships on different levels of the design process (functions, effect, working principles) is generated within the pinngate-project. As with design catalogues, these descriptions of basic solutions provide knowledge to the designer who solves a concrete design task. In addition, these basic solutions were integrated in a design process which considers the differentiation of inner and outer properties (Figure 8: original design of a new product)

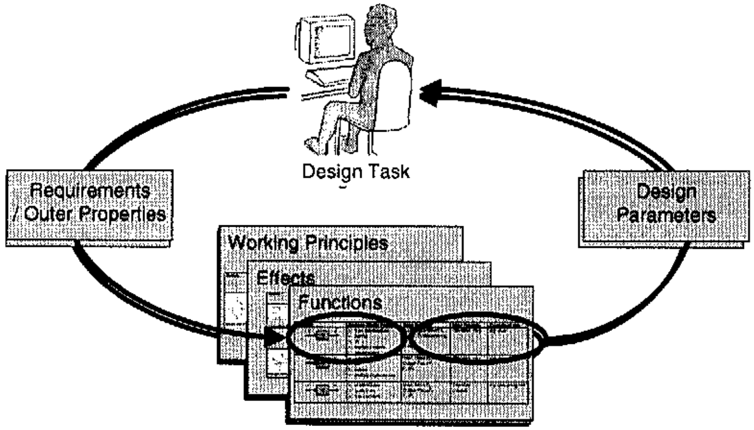

Figure 8: original design of a new product

If a designer has to generate solutions to a design task and he/she works with that approach, the following steps are necessary:

- First, the designer has to identify the task which the product has to fulfil and check for requirements. Then the requirements can be transformed into a standardized set of outer properties. The approach will offer a category-system and a standardized set of outer properties to support the designer working on that step.
- The designer can access the data-base where basic solutions are stored. The outer properties are linked to different hierarchy levels in the product design process (functions, effects, working principles). On each level all the solutions in the database are narrowed down to a solution cluster.
- By choosing any of the solutions that are still in the cluster, inner properties and relations are given. Thus, the designer not only finds suitable basic solutions to his design task. He also obtains design parameters to vary and optimize the found basic solution.

6 Summary and Outlook

In the paper, an approach which is generated within the "pinngate"-project at the department pmd at the Darmstadt University of Technology is shown. The sub-systems of the project were described. Then several methods for supporting the finding of solutions were discussed. Based on the discussion different potentialities were pointed out. Then the approach to supporting the finding of solutions with the pinngate-system was shown. The approach considers different categories of properties of technical systems to provide basic solutions in a knowledge base and to integrate this basis into the design process.

At the moment a number of basic solutions on the different levels are described according to the approach. The description has already been transferred to a first computer-prototype. The defined process is being tested on some easy design tasks. A limited number of examples for learning documents can be derived.

The next step will be to finish the work on the database and to fill it with a larger number of basic solutions. Then the transferability of the approach to more complex design tasks and different types of learning documents will be tested.

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