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SELECTING AND COMBINING METHODS FOR COMPLEX PROBLEM SOLVING WITHIN THE DESIGN PROCESS

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1. Introduction

The fast development of innovative products requires an efficient application of methods during the entire development process [Franke 1995]. Many methods exist, but often the user does not know which methods are appropriate to support the specific task. Furthermore, he is not able to spend time to deal with the efficiency of different methods for selecting the suitable ones. For the retrieval of compressed method knowledge, so-called modular systems of methods are available (e.g. [VDI 2221], [Ehrlenspiel 1995]). A modular system of methods is a systematically ordered method collection, that supports the selection of methodical aids for specific working steps of a superior process. Still, the modular systems provide rough aids for the selection by assignment to one or two parameters only, e.g. to the step of the development process or to the relevant phase of product life cycle.
Other important selection criteria are not taken into account or have very unprecise and not clearly differentiated values, e.g. the values “lengthy” and “fast” as characteristics for the attribute “time exposure for the use of method ” [Helbig 1994]. For this reasons, it is impossible to reduce the variety of methods to some suitable ones. Important selection criteria are e.g. the necessary input information and method experience for successful application. In addition to the selection of methods assisting well-defined single working steps, it is essential for the desired support of the entire design process, to combine methods compliantly to a complete sequence [Franke 2003].
Likewise, the method combination is appropriate to increase the number and the quality of results of complex working steps, e.g. while searching for working principles.
Within the scope of the research project “GINA”, the Technical University of Braunschweig developed selection concepts to find suitable methods easily by deploying relevant task and user specifications. For compatible combination of methods, two procedures are pointed out which support single working steps and entire design processes. These procedures aim to advance the quality of design results.
In this way, it is important that the approaches can be assisted by computer because of a high formalisation. Exemplary, the concepts are described by the method application of the conceptual design phase according to [Pahl/Beitz 1999].

2. Selection of methods

This paper presents two for the practical use relevant approaches to select methods. Thereby, the methods are chosen by assignment to working steps of a superior process and by assignment to method attributes. These mechanisms can be applied both independend from each other and in combination.

2.1 Method selection by assignment to working steps of the design process

In many cases the performing working step is the only or at least the most relevant criterion for the method selection. Because of this, the user has to be able to choose methods by assignment to these working steps of a superior process, e.g. the classical design process according to [Pahl/Beitz 1999]. The assignment of methods to design steps based on the subdivision of the working steps and the steps supporting methods into a set of non-interdependend basic activities, e.g. prioritising and analysing [Zanker 1999]. These basic activities are non-divideable and describe the character of methods and design steps in detail.

The basic activities of a working step can be classified into main and assisting activities according to the importance of the basic activity for the design step. A main basic activity is essential to receive the result of the working step. An assisting activity supports only the procedure to receive the result. For example, the basic activity “evaluating” is a necessary part of “evaluating principle solution variants” and for this reason a main basic activity. However, the weighting of evaluation criteria is not necessary for evaluating, so that the basic activity “prioritising” is an assisting activity.
The basic activities of working steps and methods are formulated identically. Therefore, the methods can be assigned to the working steps by the congruence of the basic activities. A method is suitable for the support of a design step if at least the main basic activities of the design step correspond with the basic activities of the methods.

The assignment using the congruence of basic activities helps to identify the characteristics of design step and method. This knowledge can be used to adapt methods to changing boundary conditions, e.g. for the support of delocated cooperation projects. Furthermore, this approach simplifies the computer-aided method selection, because the single definition of basic activities enables an automatic assignment to process steps.

Figure 1 shows the assignment of methods to working steps of the conceptual design phase using the congruence of basic activities. The dark-grey caskests represent the main basic activities, the light-grey ones the assisting activities.

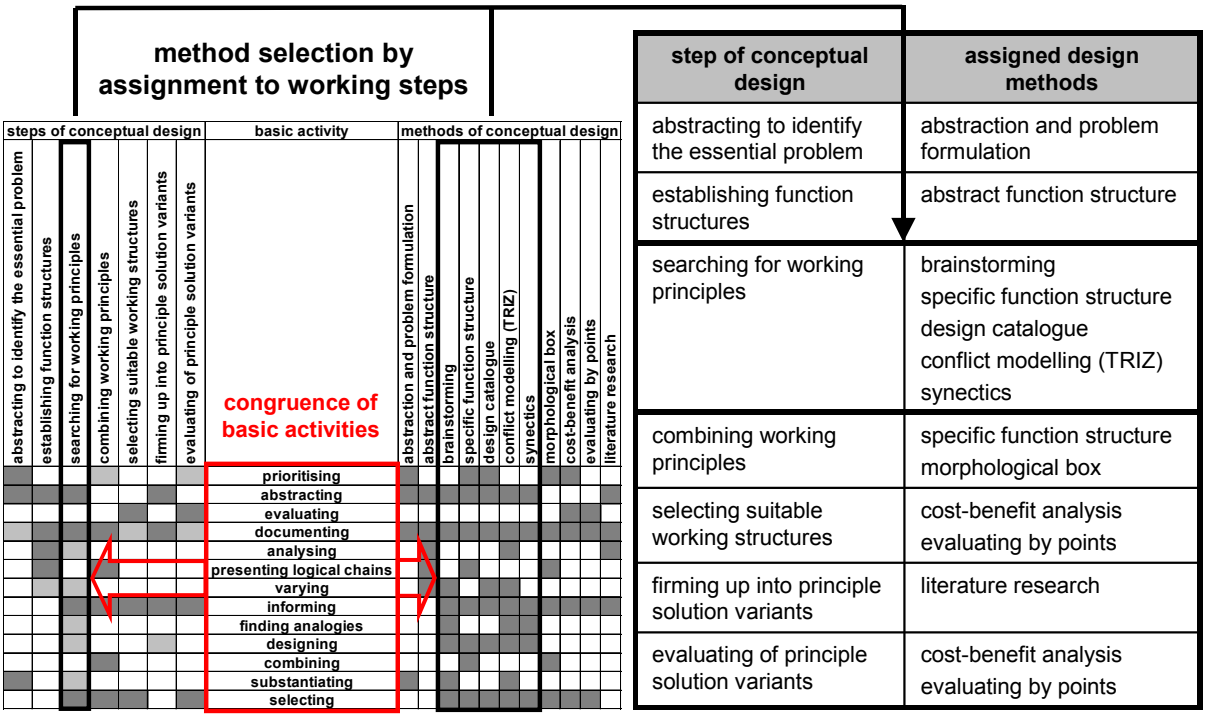

Figure 1. Method selection by assignment to working steps (excerpt)

2.2 Method selection by assignment to method attributes

Another approach for the method selection is that a method is suitable for a specific field of application because of its structural properties. The fundamental idea of this approach is that the essential properties of a method can be described by various non-interdependend attributes. Each property of a method can be represented by one characteristic value of an attribute, so that a method is definitely characterised by a combination of characteristic values. For a clear method selection, it is important that the combination of the characteristic values of one method differs from the combinations of other methods. The suitable method attributes und characteristic values are identified by analysis of the method structure, by empirical investigations and by analysis of relevant literature (e.g. [Helbig 1994], [Pahl/Beitz 1999], [Schlicksupp 1998]).

The attributes describe the structure of the method, e.g. the purpose and procedure to reach the goal of the method, and the necessary user conditions, like the suitability for single or team work and the time exposure. Further, suitable working aids, information about the representation of results, input and output parameters (shown in figure 3) are given as method characteristics.

If the values of the attributes correspond with the prevalent boundary conditions of the task, the method is appropriate for this application. Figure 2 illustrates the method selection by assignment to method attributes.

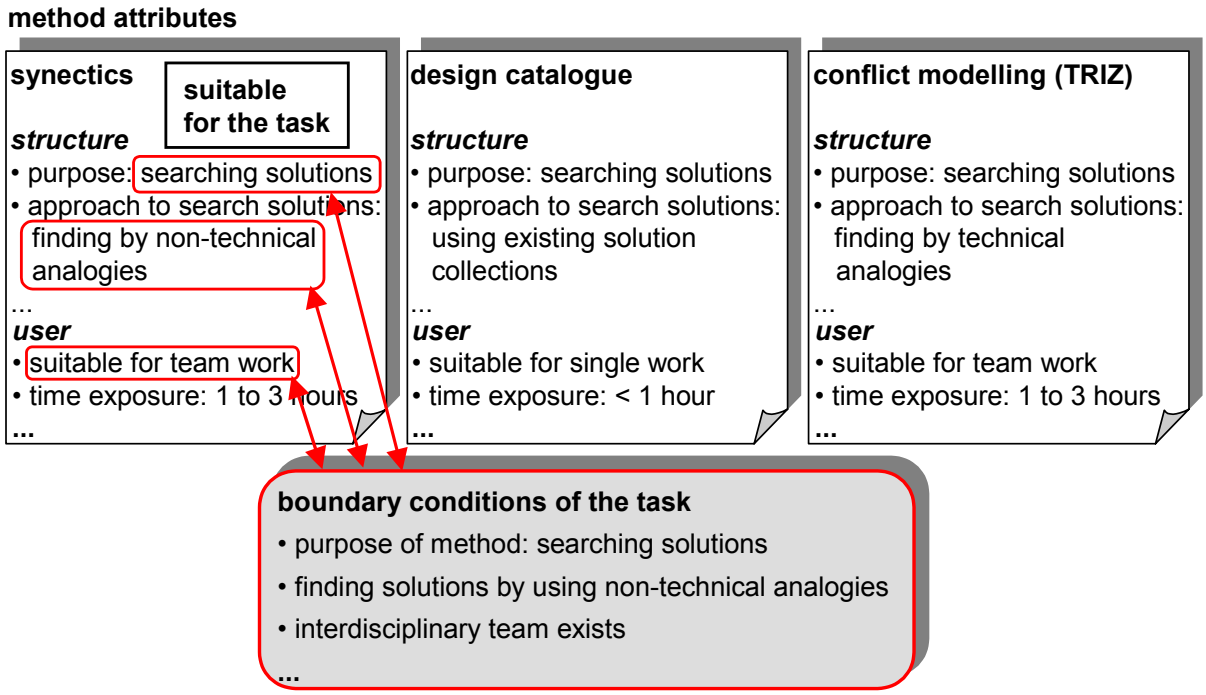

Figure 2. Method selection by assignment to attributes (excerpt)

3. Combination of methods

The combination of methods has two general objectives. One the one hand, the user aims to a method combination for the spanning support of the chronological order of working steps within the design process [Birkhofer 2002], e.g. in the conceptual design phase from the step “establishing function structures” to the step “evaluating principle solution variants”. On the other hand, the results of complex single working steps, e.g. “searching for working principles”, can be improved by using a sequence of methods [Schlicksupp 1998]. In the following, concepts of method combination are described for both objectives.

3.1 Combination for the support of processes

The design process can be described by a sequence of phases. Moreover, each phase consists of a sequence of working steps [Pahl/Beitz 1999]. For efficient product development, the user desires methodical support for each working step, so that methods have to be applied in an chronological order. In this connection, the questions arise which methods can be linked with other methods and which requirements have to be fulfilled for a compatible combination. As a result of the investigation of these questions, an approach to combine methods is described which correspond with the statements of literature (e.g. [Pahl/Beitz 1999], [Ehrlenspiel 1995]) and the experiences collected in design projects.

The approach builds on process theory [Hubka 1973] and describes a method as a process that transforms given input information into defined output information. For example, the input information of the method "morphological box" are partial solutions, partial functions, physical effects or chains of physical effects. The output information are working structures.

A combination of methods requires that the relevant output information correspond with the relevant input information of the following method. Does a correspondence not exist, the methods cannot be combined directly. In this case, further intermediate operations or methods have to be applied to adapt the input parameters to the desired output parameters. For example, the application of the specific function structure is not possible after using the abstract function structure. The abstract function structure provides "energy" in general as output information, but the specific function structure requires "functional quantities" as input information, e.g. displacement, velocity or force. For this reason, a transformation of "energy" in "functional quantities" is necessary, e.g. with the aid of an analysis of physical correlations.

Figure 3 shows the combination of several methods which support the activities of the conceptual design phase. The methods are represented as black boxes with the appropriate input and output information.

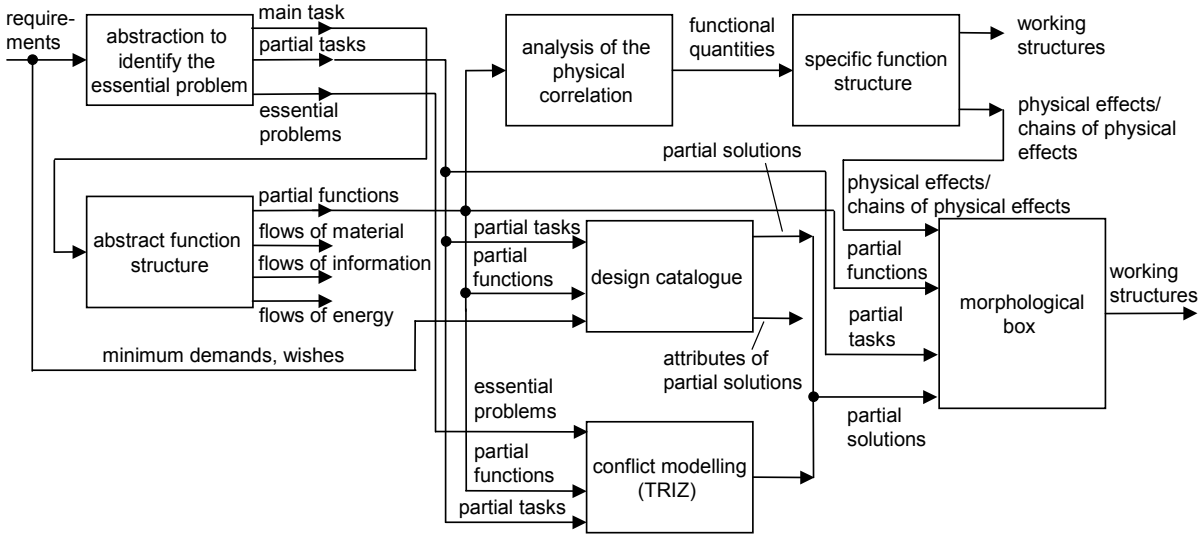

Figure 3. Combination of methods for the support of the conceptual design phase (excerpt)

3.2 Combination for the support of the working step "searching for working principles"

Normally, many of the occuring problems in design process are very complex, so that these problems cannot be accomplished in one single step of problem solving [Schlicksupp 1998]. The desired working results are only obtainable by application of various, successively applied methods.

A typical example of a complex design step is the search for working principles which can be supported by a multitude of very different methods, e.g. brainstorming, bionics and literature research. The purpose of this working step is to find many suitable solutions in a short time.

In practice, different methods are used to search for working principles, but the methods are selected and combined intuitively, so that in most cases the methodical support does not lead to the desired results. Because of this, a sequence of methods was developed systematically which assists the fast finding of high-quality solutions. This approach was verified in many industrial applications. Figure 4 shows a guideline for the support of the design step „searching for working principles" exemplified by a subset of methods.

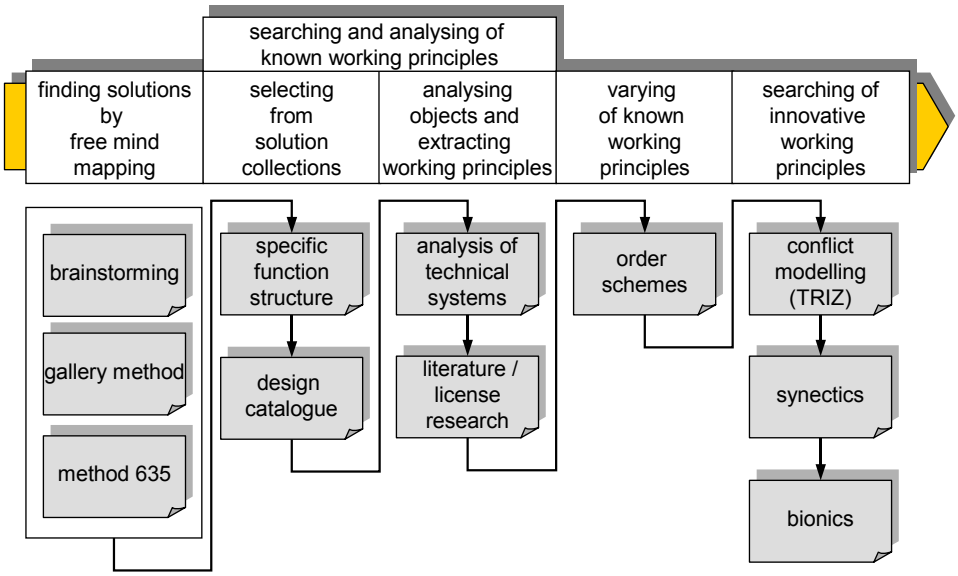

Figure 4. Combination of methods for the support of the working step "searching for working principles"

The prerequisition of this approach is that all input information of the supporting methods are known. The input information of the step "searching for working principles" are the relevant partial task, partial function or functional quantities.

The procedure is compounded by five procedure steps. Thereby, the procedure starts to access to the stored knowledge of the user with the aim to create first intuitive solutions. The next four steps comply with the strategy to search working principles starting from known and existing solutions up to unknown solutions. By using this strategy, time exposure rises and the probability to find suitable solutions decreases from step to step. After each step it has to be checked whether the existing solutions are sufficient and the search can stop. If the solutions are insufficient, the next procedure step has to start. This procedure is only an application reference. Therefore, single steps could left out depending on the prevalent boundary conditions of the task and the knowledge of the user.

In the first step, the user should apply easy manageable intuitive methods which bring out the known solutions and generate relaxed new ideas by free mind mapping. For this purpose, methods are suitable which generate a variety of solutions by team work. Examples for these methods are brainstorming and the gallery method.

In the following, methods are suitable which use existing solution collections, like design catalogues and the specific function structure. These methods enable a fast access to existing solutions because of a structured preparation of knowledge.

The third step supporting methods use known technical solutions as well. For the application of these methods, existing solutions have to be analysed first and suitable working principles have to be extracted in the following. Examples for this methods are the analysis of technical systems and license research.

In the fourth step, methods should be used which search for working principles by variation of know solutions, e.g. order schemes.

Finally, the fifth procedure step enables the finding of innovative working principles by using analogies. The search of innovative solutions can build on technical analogies, e.g. by applying the

method conflict modelling according to TRIZ, or the user can be inspired by non-technical analogies, e.g. by natural examples within the method bionics or by using synectics. In this connection, it is appropriate to use technical analogies first because that requires less abilities to abstract than e.g. synectics and assumes no knowledge concerning natural systems in contrast to bionics.

4. Conclusions

In this paper, two concepts are described which enable the user to select methods easily for the support of a definite design task. With the aid of corresponding basic activities, methods are assigned to working steps of a superior design process. Another concept for the selection based on the assignment to method attributes. A method ist suitable for the task, if the characteristic values of the attributes are identic with the prevalent boundary conditions of application.
Furthermore, a systematical approach to combine methods for the complete support of entire process chains is described in detail. A compatible combination is possible, if the relevant output information of a method correspond with the relevant input information of the following method. A further field of application for combining methods is the efficient methodical support of complex working steps. In this connection, a guideline for the application of various methods supporting "searching for working principles" is presented. The guideline makes is possible to generate many high-quality solutions in a short time.

Acknowledgement

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