Orientation support in product development

Author(s):
Dünser, Thomas

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ORIENTATION SUPPORT IN PRODUCT DEVELOPMENT

Thomas Dünser

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Abstract

This paper presents instructions to support finding the best design step sequence for product development. Aiming at the detailed navigation questions of practical development, it can be seen as an enhancement to the more general VDI 2221. The proposed design procedure supports dealing with the uncertainty by giving a better orientation to the goals throughout the design process and so to generate as efficient as possible the relevant product knowledge.

The backbone of the proposed instructions is a special product model called "influence net". It enables to do objective decisions that may be checked when more product knowledge is available, which is most important for dealing with the uncertainty. Furthermore, the influence net gives precise answers to all decision and orientation questions that arise during product design. It allows to integrate more complex aspects as dynamic goals, decisions that take into account detailed market segments and the adoption of the dimensioning factors for each variant.

1. Introduction

A major challenge of product development is to realize a successful product as efficient as possible. Besides creative solutions, customer orientation and a suitable procedure are decisive for this. The best known proposal of a design procedure is described in VDI-2221 [1] and in Pahl / Beitz [2]. Both relate to a general procedure scheme (task clarification – conceptual design – embodiment design – detail design), which represents almost every problem solving process, but it neglects question as:

- When do we have to design the different detailization levels of component Y?
- When shall we decide about component variants?
- Is it necessary – and when – to redo a previous design step? (iteration)

Nevertheless, such problems belong to the major practical problems of each design process, since they directly relate to the efficiency and effectiveness of product development. A support for finding the best design procedure on the level of working packages sequence would be of great relevance.

This paper proposes an approach to solve this problem that may be seen as an enhancement of the basic procedure of VDI 2221 [1].

To keep the orientation the customers' wishes, resp. the development goals, is an important part of such a design sequence. As in product design, most of the decisions made base on assumptions that have to be verified in later steps (e. g. first decision about the product idea), the aibility of doing "objective" decisions which – in addition to that – may be checked lateron is crucial for keeping the orientation the the goals. Chapter 2 is therefore introducing a new evaluation method for system components as basis for the searched design sequence.

2. To keep the orientation towards the goals when deciding on component variants

The discussion about this topic shall start with a hypothesis which will be argued afterwards:

It is not – or hardly – possible to do appropriate evaluations of component variants with the known evaluation methods (Kesselring [2], Zangemeister [3]…) even in medium complex technical systems.

The consequence of this is that realized products may be far from the theoretical optimum regarding the development goals.

To give reasons for this hypothesis, a typical evaluation situation handled by the evaluation method of Kesselring shall be discussed:

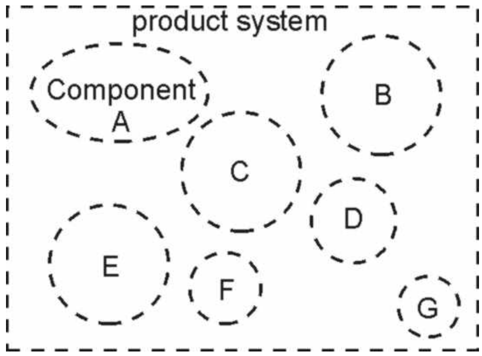

fig 1. example product system with several components

There shall be several variants of a component "C" of a technical system (see fig. 1) to be evaluated. First of all, the evaluation criteria have to be found. According to theory [2], evaluation criteria should represent the development goals. But as components usually don't relate directly to the overall goals, it is not a trivial problem to find the correct component evaluation criteria. Thus, too many, too less or the wrong evaluation criteria distort the evaluation results. In a next step, the evaluation criteria have to be weighted according to their importance. This means: Choosing a variant that is strong regarding an important evaluation criterion should lead to a better final product compared to a variant strong in a less important aspect. So the weight should represent and quantify (!) all dependencies between component C and all other components that form all together the whole product (see fig. 2). As the weight has to be estimated by human beings, its quality depends on the capacity of mind processes. But according to psychological research (e. g. Miller [5], Neissser [6]), this capacity is limited. The correct quantification of the dependencies even of small products is very hard or – in many cases – almost impossible.

In such situations, the "correctness" of an evaluation seems to be weak: the more complex the product, the higher the subjective stake, despite of having methodological support that helps to objectivize the weighting (see [4], [7]). Finally, the common evaluation method has two weak points: The determination of evaluation criteria and of their weight turn out to be critical in component evaluations.

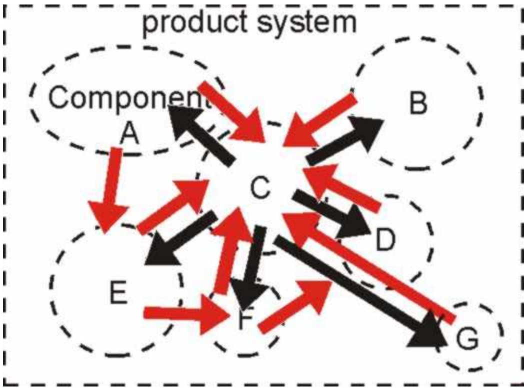

fig. 2. Possible influences between the components

In [8], the author proposes a new approach of evaluating component variants that allows to do "objective" evaluations (in the sense that all product knowledge can be respected correctly) by considering all known dependencies in a mathematical model. Due to its importance for the design sequence, it shall shortly be presented:

The method bases on a specific model of the design process: A product can be modeled as a net of attributes (knots) and relations between them (see fig. 3). Some of the attributes are relevant to the environment of the product (e. g. the customer(s)). In fig. 3. they are represented by the dots on the outer circle. All relations (or influences) are directed towards these relevant attributs, so that – with this model – the expert knowledge of the product is linked to environment's cognition. This model and the relating mathematical background is called "influence net". It represents all knowledge specific to a product (e. g. market / customers, technics, economics, industrial design, psychology) and is the core of the proposed evaluation method and – furthermore – of the design procedure to be presented later.

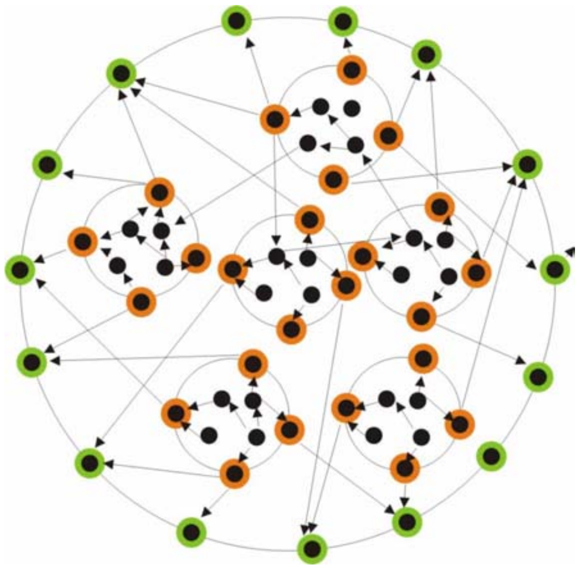
fig. 3. illustration of the influence net

Starting from an existing product, the design process either changes some attribute values (adaptation design) or it changes or creates influences and attributes themselves (new design).

The evaluation of component's variants requires the correct determination of evaluation criteria. In [8], it is postulated that the evaluation criteria of the whole product are product attributes that are seen as deficient by the environment. Based on this, the evaluation criteria of a component are the component attributes with influence on the overall evaluation criteria and – furthermore – are sufficiently general to describe all solution variants. In fig. 3, they are represented by the dots on the smaller circles. By using this postulate, the component's evaluation criteria are directly deduced from the product model. Because of this determination they are clear and precise.

The effect of one component variant on the influence net means that the evaluation attributes change to the new values of the variant regarding a reference level. This change of the values provokes a changing of the overall evaluation criteria and – like this – of the design goals. So the effect of using one variant can be calculated precisely using the mathematical model from the influence net. More information about this can be found in [8]. At this point, it is important to state that by using this method, components evaluation becomes objective regarding all present knowledge and – most important – enables to check in later steps, if the assumptions made were correct. Furthermore, it is possible to integrate all relevant product knowledge areas, like technical and economical aspects, into one only evaluation.

3. Aspects to consider in a design sequence support

1. *Deciding on working packages sequence*

   The dependencies of working packages – covering (sub-) components and levels of detailization – are very important for deciding on the design sequence. It has to be clarified if the dependencies allow a decision or what questions and working packages have to be done before the decision. One typical example of such interdependencies are influence loops that cross the component's system border.

2. *The product knowledge increases / changes during the design*

   All design decisions partly have to rely on assumptions on the future relations. The decision about the new product idea, for example, bases on the assumption that the technical implementation will lead to the most successful product among all ideas. But at this point, nothing – or almost nothing – is known about the product except of some deductions of general knowledge. Because the specific product knowledge increases with every design step, the assumptions made have to be verified later on.

   Assumptions can also be falsified and it is essential to know for chosing the right design procedure, if the related decision would have been different with the increased knowledge. If yes, the question of redoing the questionable decision has to be considered.

3. *Development goals can change during the design process*

   The first reason for the changing goals is an uncomplete initial goal description (running targets). Additions or changements of the goals that appear in the ongoing design might have led to different decisions of solutions.

   The second reason for changing targets results from the fact that goals are deduced by one state of the environment. Because the environment is dynamic, the goals must be dynamic, too. Typical design goals rely on subjective assessments of the customer of the most important aspects to improve and base on a certain reference level. If the reference level changes (e. g. by a competitor's product) or new information happen to change the importance assessments (e. g. consumer tests), the goals might change even during the design process.

4. *Market segments have different effects on decisions*

   Each market segment has its own goal (e. g. different importance assessments), so that design decisions may result differently.

5. *The adaptation of dimensioning factors is important for a correct variant evaluation*

   Often, dimensioning factors of one component relate to assumptions made when designing another component. Such assumptions may be better for some variants as for others, so that the evaluation result is distorted. Therefore it is necessary to adopt the dimensioning factors for every solution variant to a momentary optimum.

4. Proposal of a design sequence support based on the influence net

The design sequence support consits of a loop of ten steps

1. To find out which component has to be studied first / next, it is necessary to know the attributes of the biggest influence on the development goals. Two pieces of information are relevant: Firstly, the impact of changing one attribute on the design goals (so called "influence strength") which can be extracted from the mathematical influence net model. Secondly, the estimation of how much an attribute might be changed. The multiplication of those two values results in a measure of importance, that indicates which component has to be studied next.
2. The design phasis of the chosen component returns several solution variants that have to be reduced to the most promising one. The variants are represented by different influence models towards their evaluation criteria. The criteria themselves have a specific influence strength on the design goals that results from the overall influence net. The influence strength is used for the evaluation.
3. Before a decision can be made, the influence strengths have to be checked on uncertain factors that result from unknown components. If the decision is too uncertain and its impact on the decision can not be neglected, it indicates that the related component has to be analysed before the decision.
4. Another check before the decision can be made is about the certainty of dimensioning factors of the component. If it is not clear if the wished value is realizable, and it then has an effect on the decision, the related component should be analysed before the decision.
5. As the influence net only considers certain knowledge that results from earlier design steps, integrating experience knowledge about the following steps (e. g. detailization) improves the quality of a decision. By doing this, it is very important to objectivize this deductions and to enhance the certain influence net with the assumed relations and their influence strengths. Like this, the future aspects might not be over-estimated.
6. In a next step, the design goals should be checked as to actuality.
7. The dimensioning factors have to be adopted (momentary optimized) for every variant. The optimatization space is given by the influence net.
8. Due to the changed basis for all former decisions (changed goals, increased product knowledge), it is necessary to check their correctness. This step is only possible, because all decisions made are oriented towards the same measurable goals (according to the evaluation method described in chapter 2). If any assumption turns out to be wrong, a repetition of the related step has to be discussed (iteration). Within this discussion, the development cost aspect has to be respected.

9. The evaluation of the (set of) component variants can then be performed and the decision be made. This step preliminary fixes a new part of the whole influence net and – like this – new product knowledge that is used for further design and decisions.
10. The new attributes of the chosen variant define new specifications and evaluation criteria to the surrounding components.

Now it is possible to start over with point 1 for the next components, up to all detailization steps are complete for all components.

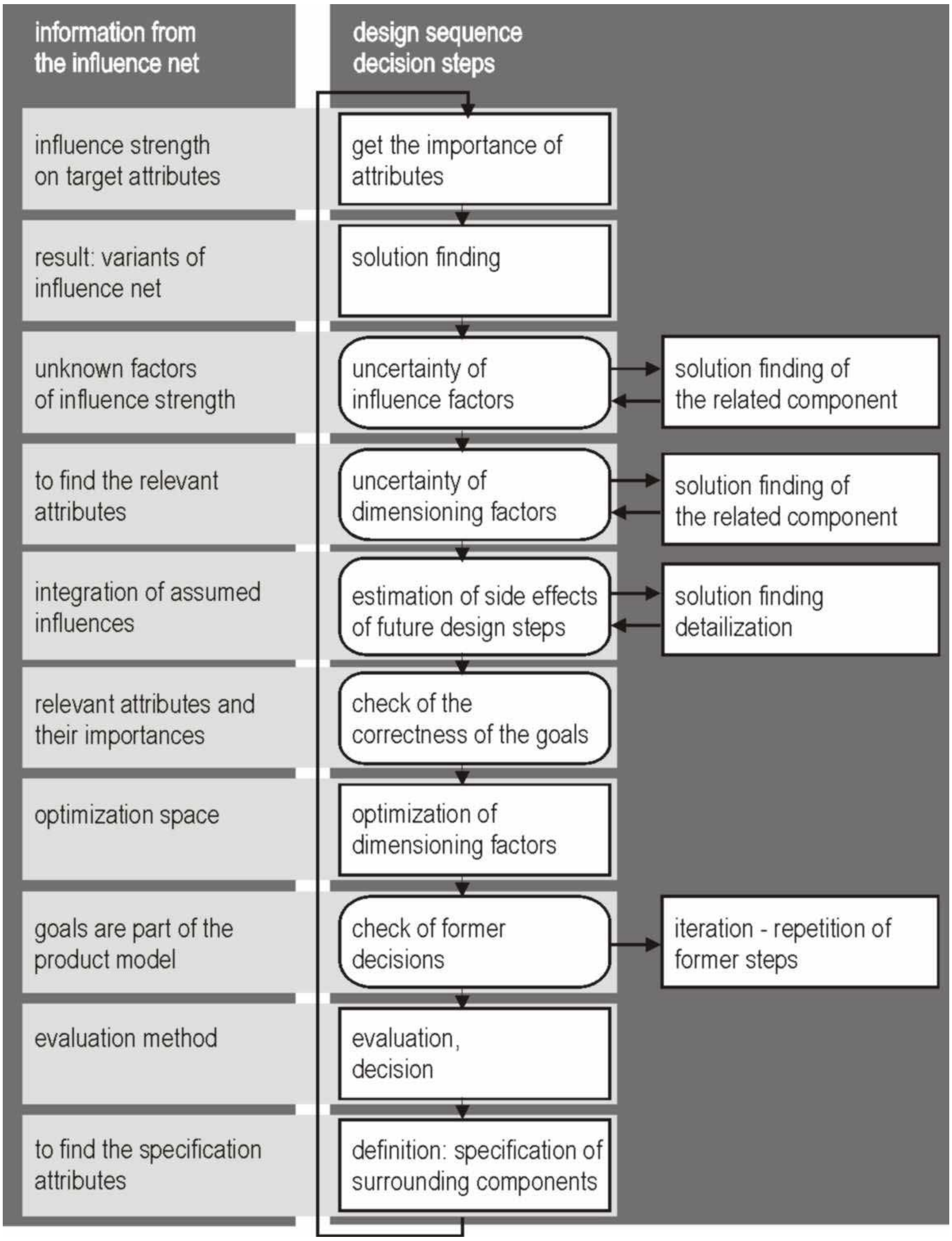

fig. 4. synthesis of the design sequence instructions

5 Conclusion

The proposed design procedure instructions in combination with the influence net support

- the decisions about the working package sequence in order to realize as efficient as possible the best possible result
- the keeping of the orientation towards the development goals throughout the design process
- the handling of more complex aspects as dynamic goals and detailed market segmentation to realize a product better adopted to the market.

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Dipl. Masch.-Ing. Thomas Dünser
Institute for Mechanical Systems
Tannenstrasse 3
ETH Zentrum, CLA E 16.1
8092 Zuerich
Switzerland

Tel: +41-1-632 51 04
E-mail: thomas.duenser@imes.mavt.ethz.ch