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COMBINING DESIGN AND CREATIVITY TOOLS

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1. Introduction

The design of machine components and other complex products can be divided into four phases requiring different levels of creativity [VDI 1993], [VDI 1997]: Clarifying the task, conceiving, designing and working out. Usually, these tasks are carried out using different tools from simple text processors to FEM and other simulating and calculating tools. Most of the designers work separately using their own tools without much communication with their colleagues.
The "Active Semantic Design Network" (ASK) developed at the Institute of Machine Components [Marx 1998], [Kopsch 1998] supports the designers in all four phases and thereby drastically reduces the loss of information which usually occurs when switching from one tool to the other. All information gained in the four phases is stored in the system, enabling the designers to easily carry out loops in the design process. Thanks to the segmentation the designers can even change the concepts for one part while another one is already completely worked out. By using semantic modelling, the designers can set up the design as a semantic network in the design system from which the design system derives the CAD and rating model.
Since all the information gathered during the design process is stored in the system, the designers can start a creativity session whenever the need for one arises. It does not matter in which phase of the design process the designer in question is or what the other designers are doing at that moment. All designers taking part in this creativity session are notified about the problem and can obtain further information about it using the ASK. Then they start the creative process which is - if possible - recorded and stored with the design.
This paper describes very shortly which creativity techniques were regarded as useful for designers using the ASK, potentially in different locations, and how they were implemented in the context of the ASK.

2. The ASK

The concept of the Active Semantic Design Network described in detail in [Marx 1998] and [Kopsch 1998] can be subsumed as follows:
Firstly, according to phase one of [VDI 1993] and [VDI 1997], the actual design task has to be clarified depending on the market demands. The requests and limitations as well as the tasks to be carried out build the basis of all following steps. They are often not yet precisely defined or are subject to later changes and are recorded in the list of requirements on top of the modelling surface, in the background of figure 1.
When the list of requirements has been filled with all the information available at the moment, concepts are derived, described and rated. Creating the list of requirements and deriving concepts are the tasks that are most likely to employ creativity techniques. Different concepts may be kept for later

comparisons. The result of this step is a basic function structure with many degrees of freedom regarding the later implementation.
This function structure is then transformed into an outline of the technical realisation, again potentially incorporating several different possible concepts for parts of the task, e.g. a worm vs. a spur gear drive. In this step, formulas and semantic connections between the parts are added to the parts to create the semantic network which allows for automated recalculations after minor changes and the propagation of changes through the entire model.
In the last phase the outline created before is worked out, dropping all variants and specifying every part in detail. For product families, the variants of the actual family are worked out whereas different design approaches created in phase three are dropped. Since modular products often consist of more or less independent designs, it can be more suitable to split the project into several separate designs in this step. Size ranges, however, have to remain in one design for the system to function correctly.
These four phases require different tools to support the designers which are combined in and controlled by the program. The basic surface offers the drawing space for all phases and the buttons to control the program (Fig. 1, background). Depending on the required functionality different third-party and self-programmed tools are employed, e.g. the CAD-Software Pro/Engineer for visualisation and optical collision detection, a gear rating tool or videoconferencing/creativity tools.
The phases can be displayed all at the same time or only the desired ones to reduce the complexity and make it easier to follow the design process. The view of the technical realisation can be zoomed to show only the main structure or more details up to every single screw. Also, the display of connections and relations between the parts can be turned on and off to simplify the navigation in complex design networks.
Since in the early phases of the design process the information about dimensions is usually quite vague, the system allows the use of intervals instead of discrete values. These intervals are narrowed during the design process until they finally lead to discrete values.
To create a design model, the designers use modules representing the actual parts and connect them by semantic relations like “mounted on”, “drives” etc. The resulting semantic network is the basis from which the rating and CAD model are derived automatically, thus exonerating the designers of time-consuming and superfluous routine work.
While the designers set up the semantic network, the active component forwards all new information through the net and thereby supplies all designers with the most recent rating results and helps to narrow the intervals set up before due to further external influences.

3. Creativity techniques

Creativity is one of the oldest features of human beings and has been commented on by many philosophers since the antiquity. Until the 20th century, however, it was considered an artists gift rather than an engineer’s. The modern research on human creativity started in the USA in the 1960s as a consequence of the Russian head start in the race to the moon. During the 1960s and 1970s, it was a field in which much research was done. The results of this era are our commonly known creativity techniques. Today the techniques are well known but seldom employed because a) in the 1970s some companies tried to introduce creativity techniques without proper training of the employees resulting in dismal failures and b) the efforts and expenses for conventional creativity sessions are high. According to a study by Rolf Berth [Berth 1985] 31% of the companies didn’t ever even try creativity techniques because they feared failures. Only 13% of the companies employed creativity techniques, 70% of which repeatedly. This underlines that creativity techniques can be very helpful if applied correctly and that there is need to faciliate the use of these techniques. Recently, there have been some developments to support single user techniques, especially MindMapping based ones, by software, but very little has been achieved in supporting distributed participants like in the modern design process.
The aim of this project, sponsored by the Deutsche Forschungsgemeinschaft, is to adapt those creativity techniques (single and multiuser) that are suitable for it to the collaborative computer aided design process using the ASK.

3.1 Systematisation of the creativity techniques and fields of application

There are five elementary problem categories:

- Analysis problems,
- Search problems,
- Constellation problems,
- Picking problems and
- Consequence problems.

Only the first three of these five categories are suitable for creativity techniques. The most suitable methods for the different phases of the design process are discussed later.

The creativity methods can be divided by different criteria, for example according to the underlying thinking principles or according to the working principles. For this paper, the grouping according to the principles of the methods is used. This splits the methods into six groups,

- Brainstorming and variants
- Brainwriting and variants
- Methods of creative orientation (heuristics)
- Methods of analogies (synectics)
- Methods of systematic structurisation (morphological box) and
- Methods of systematic problem specification.

This list does not cover meta-techniques such as mind mapping which are primarily used for other purposes but can also lead to more creative results.

Since the ASK is intended for distributed designers, potentially even in different time zones, the choice of creativity techniques is limited. If the designers working together in different locations are familiar with each other, group sessions can be held using CSCW-tools. The direct interaction is replaced by videoconferencing; the whiteboard is a virtual, shared whiteboard etc. This requires much discipline and therefore hinders the creative process, but can nevertheless be useful. For designers in different time zones it is usually not suitable to use online creativity tools since it requires one side to work late and the other to start early. This should only be done for time-critical problems that require the interaction of all designers involved. If the problem is not time-critical, one of the brainwriting methods or one of the methods of systematic structurisation (morphological box) can be used in offline-mode.

4. Implementation

To test the suitability of the different creativity techniques for distributed designers, one example of each creativity method has been chosen for prototypical implementation in the ASK. These are briefly introduced and discussed. Since this is an ongoing work, the results are partly preliminary. Hints on how to introduce creativity techniques in companies can be found in [Wiedemann 1980].

Since not all designers are familiar with the different creativity techniques, the first page (fig. 1) is an introductory page which helps choose the right technique for the given problem. In the next step the technique is presented and hints for the execution are given before the actual session starts.

4.1 Brainstorming methods

The best known creativity method is certainly traditional brainstorming, so it was the first technique to study. Brainstorming is best performed in a group of four to seven participants, ideally from different branches of the company to induce different points of view. The chairperson (usually also writing the protocol) has to be very well trained to keep the session in flow and prevent hindering or aggressive comments. It is best suited for search problems and most often used in the early stages of the design process, i.e. writing the list of requirements and developing the basic function principles. The basic rules are:

- Every participant is encouraged to develop and express their thoughts
- All suggestions are to be taken as input for own thoughts
- No criticism in any form is allowed

The goal is to develop as many ideas as possible, no matter whether they make any sense. Due to this form of interaction it is unconditionally necessary that the participants of the creativity session can easily listen to and watch each other. If videoconferencing equipment is available, it can be applied by distributed designers working at the same time. The results are produced vocally and recorded by the chairperson. Since the participants have to interact it is necessary to build a basis of understanding and trust among the participants for the session to be effective. Compared to creativity sessions with all participants present the distributed session is more complicated but can produce similar results.

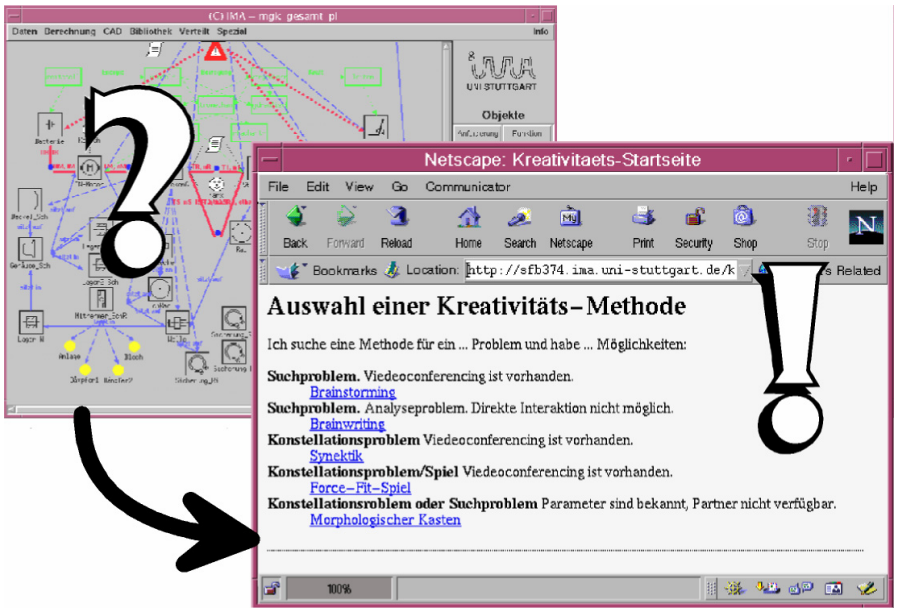

Figure 1. Starting a creativity session

4.2 Method 635 (Brainwriting)

The basic principle of all brainwriting methods is that the participants write their ideas down on a piece of paper or fill in forms. The main difference between the techniques is the handling of the ideas during the session. The field of application is similar to that of the brainstorming methods. The best known brainwriting method, method 635, was chosen for research.

This method is almost ideal for distributed designers since the process in the standard form involves six designers (participants) who write down three suggestions on a piece of paper and then pass it to the next participant. For distributed designers the process has to be modified slightly because in the normal process the participants meet to analyse and define the problem first. This step has to be carried out by the designer starting the creativity session who then informs the other designers via videoconferencing or e-mail.

In the prototypical implementation the designers communicate via a web-interface in which they fill in their ideas and then send it to the next participant. The results are stored on the web server and can later be evaluated by the designers. Apart from the changes in setting up the session, this method is the one with the least differences between the local and the distributed version and has proven easily usable for distributed designers with little extra efforts.

4.3 Methods of creative orientation

The methods of creative orientation can be subdivided into heuristics, modification of the point of view and bionics. All these principles help in directing the search for solutions in certain directions and are no real creativity techniques but rather problem solving methods.

The most common heuristic technique is better known as Osborn-Checklist. It is suitable for one person trying to optimise a given solution by asking himself or a group standardised questions such as “what can be replaced/combined/resized/added/inverted/...”, where each question can be answered in a group using brainstorming etc. if deemed helpful.

There are three common methods changing the point of view, Walt Disney method, three doors method and six (thinking) hats method. These use three chairs, three doors or six hats to symbolise different approaches to a problem. For the six thinking hats [DeBono 2000], the six hats represent objectivity, personal feelings, risks, advantages, creativity and overview. This technique can well be employed for creativity sessions by distributed designers using videoconferencing, but it requires skilled participants that can change the point of view as demanded. The process is otherwise similar to brainstorming, so the same comments apply here too.
Both heuristics and point of view methods cannot explicitly be supported by means of computer aided tools, therefore only instructions for the participants were added to the design system. Video-conferencing has always been a part of this system. Bionics are similar to synectics and were therefore not researched separately in detail.

4.4 Synectics

The outer conditions of a (classical) synectics session are similar to those of a brainstorming session. The procedure falls into three phases: First the problem is described and analysed, then it is alienated and finally new solutions are developed by combining the alienated ideas with the original problem. Synectics are most often used to develop variants and in constellation problems. There are a number of variants to this method which alter the actual procedure slightly, but all rely on the interaction of the participants. Therefore, the effects of distributed designers using this method are similar to those of the distributed brainstorming: If the designers are familiar with each other and the method, they can carry it out using videoconferencing tools. The combination of synectics with thoughts of imagery [Gruber 1962] has led to a new approach where the participants are confronted with arbitrary images to seed the alienation and creation of solutions. This modus operandi also seems to work well with distributed designers who are not connected via videoconferencing. Further research is needed to validate these first results.

4.5 Methods of systematic structurisation

The methods of systematic structurisation are comparatively complex and thus are best suited for complex problems. They are often applied to create new product ideas from very vague specifications. They require much time to prepare and to execute. All methods are based on existing solutions or at least focused on the solutions. They are therefore better suited to choose solutions in modular surroundings than for very innovative solutions. Some, like the morphological box (fig. 2), even apply other methods for the creation of basic solutions.
The two best known methods of systematic structurisation are very similar for the user: Morphological box and functional analysis. Since the process is longer it cannot be discussed here.
The only distributed application for a morphological box that appears efficient is to ask a large group for their opinions when the preparatory steps have been carried out by a local team that prepares the actual morphological box and hands it to the distributed designers for their vote. Since this is a poll rather than a creative process, the methods of systematic structurisation are not regarded suitable for distributed designers.

4.6 Methods of systematic problem specification

The methods of systematic problem specification are no creativity techniques themselves but rather a tool to detect the source of the problem or the core of the problem area. The actual solution of the problem is searched in a second step applying one of the creativity techniques.
Since the focus of this project was to research creativity techniques for distributed designers and some of these methods, like for example the KJ-method, are very time-consuming, these methods have not been looked at so far. This will be a worthwhile topic for future research.

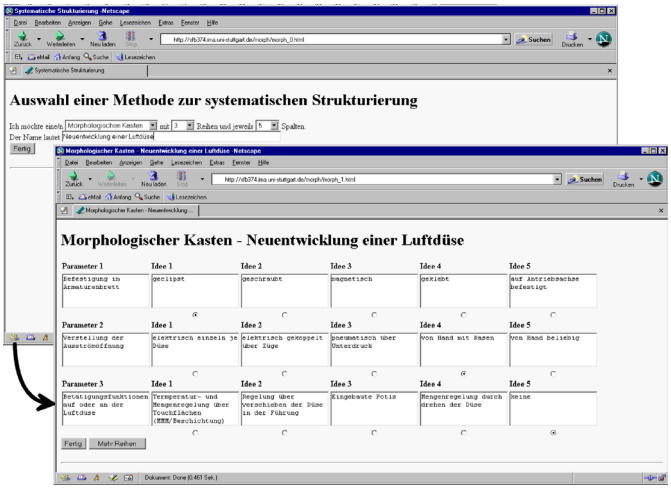

Figure 2. Implementation of a morphological box

5. Conclusions

New approaches in design are necessary to meet the market's demands for faster development of innovative products. The ASK is a tool which supports the designers in creating those products. Since many creative problems have to be solved during the design process, creativity techniques have been integrated into the design system to try to combine the distributed designers' creativity.

The main problem is that most of the creativity techniques are based on the participants' interactions and are therefore hard to transfer to designers which are at the most connected via videoconferencing. For distributed designers in different time zones it seems not suitable to apply online creativity techniques at all and offline methods (like method 635) can only be used for problems that are not time-critical.

The online methods can be carried out using CSCW-tools, but they require a lot of discipline and are therefore less efficient than in direct sessions. It has been shown, however, that these techniques can be successfully applied by distributed designers.

Further research is to be carried out on the methods of systematic problem specification and on variants of the synectic methods.

References

Berth, R., "Kreativitätstechniken in Unternehmen", Absatzwirtschaft, Special Edition 10/1985

De Bono, E., " Six thinking hats", Penguin, London, 2000

Gruber, H. E. et al., "Contemporary approaches to creative thinking", Atherton Press, New York, 1962

Marx, P., "Durchgängige, bauteilübergreifende Auslegung vom Maschinenelementen mit unscharfen Vorgaben", Ph.D. Thesis, IMA University of Stuttgart, 1998

Kopsch, J., "Unterstützung der Konstruktionstätigkeiten mit einem Aktiven Semantischen Netz", Ph.D. Thesis IMA University of Stuttgart, 1998

VDI, "VDI-Richtlinie 2221: Systematic approach to the development and design of technical systems and products", VDI-Verlag, Düsseldorf, 1993

VDI, "VDI-Richtlinie 2222 Blatt 1: Methodic development of solution principles", VDI-Verlag, Düsseldorf, 1997

Wiedemann, H., "Mitarbeiter weiterbilden", Kiehl, Ludwigshafen/Rhein, 1980

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