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SUPPORT OF DESIGN ENGINEERING ACTIVITY – THE CONTACT AND CHANNEL MODEL (C&CM) IN THE CONTEXT OF PROBLEM SOLVING AND THE ROLE OF MODELLING

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1. Introduction

Technologically, many enterprises especially in the German speaking regions of Europe currently have no difficulties in the world wide competition of innovation. A long history of design research and a tough "puzzle about" mentality still lift these enterprises on a leading rank. But these enterprises are forced to also rationalise their development processes due to the growing competition in the worldwide markets causing shorter product life- and thus also product development cycles. Many design departments lack of a target oriented, effective process of searching solutions for design problems. "Making it work" often is the target of the designing engineers, which causes the process to fail target in time. The search for solution often is based on scattered smattering, which prevents the logically grounded reasoning about creatively found solutions.
Design methodology has not found an entrance to the enterprises and often is not applied to find more effective ways of solving the problems. Designers in industry do not find the right advice in design methodologies when they have to act in the real world of product development. In order to illustrate more thoroughly this issue with a metaphor it is just for a moment assumed that product development process is a process of "climbing up a stair". The handrail of the stair then is design methodology, which leads upward the design process, which gives a hold in certain situations. But the climbing of the stairs must be done be the designers themselves. The problem of the design process is, that within the stair of product development there are missing several steps from time to time. The path of the process often is covered with uncertainties which cause holes within the stairs. The core question challenged with this contribution is how these steps can be bridged and what can be done to fill the holes when the handrail of design methodology does not give enough hold to guide the designer on the way up to a successful product.
This paper starts with the introduction of the Contact and Channel Model (C&CM) and shows its way of application by means of a simple example. The Contact and Channel Model is a means to describe the problem on any level of abstraction, in order to provide a representation of the product as the problem situation requires. After having explained the approach, two general assumptions of "model building" and "solving design problems" will light the background in which the C&CM is settled.

2. The Contact and Channel Model approach

The core of the C&CM approach is an orderly assignment of the functions of a product to their shape, which enables designers to break up with rigid, pre-fixating representations of products. C&CM

product models by means of Working Surface Pairs (WSP) and Channel and Support Structures (CSS) force users to think about products in a more abstract way [Eckert et. al 2004].

2.1 How the C&CM works

By using C&CM it is possible to isolate an individual problem from the remaining technical system at any time of the design process and any level of detail, solve it and integrate the solution into the entire system to check the effects of the changes on the entire system.

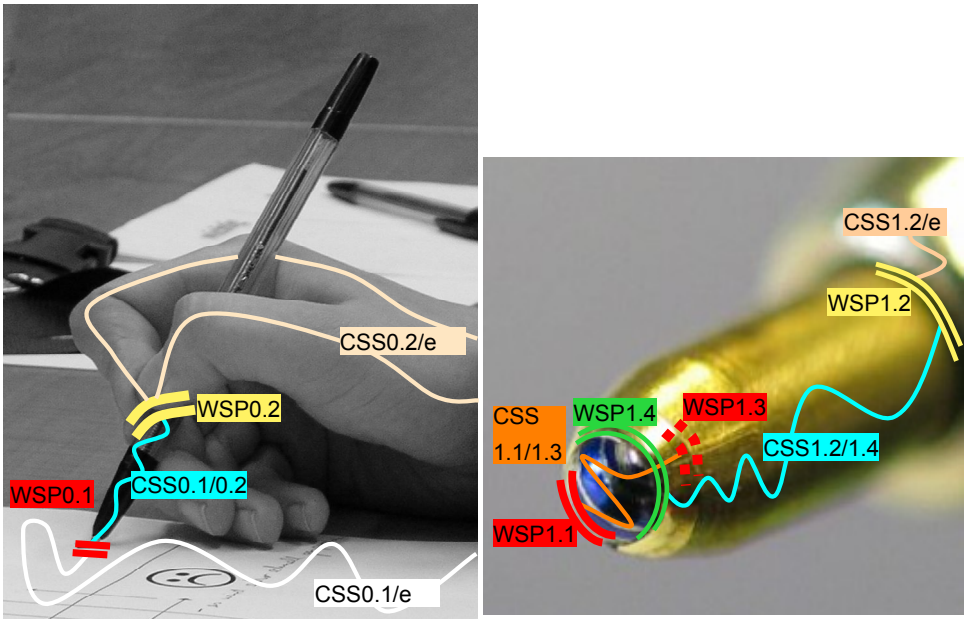

Figure 1. C&CM description of a ballpoint pen

The Contact & Channel Model describes engineering products in terms of Working Surface Pairs and Channel and Support Structures [Matthiesen 2002]. Every function of the product resides at a particular set of Working Surface Pairs (WSP) and Channel and Support Structure (CSS), because a function cannot be applied other than through these interfaces. This enables designers to think about abstract functions in a concrete way, because they can picture them at a set of Working Surface Pairs.
In terms of the C&CM approach, descriptions are generated for a particular problem through assigning a set of Working Surface Pairs and Channel and Support Structure to a specific function and searching for solutions on this clearly assigned level. The C&CM approach then picks and groups elements of the existing description in a new way, exploring in the inherent ambiguity of how elements of a description are grouped (see [Stiny 2000]).
For example the function of a ballpoint pen (see Figure 1) cannot be fulfilled unless $WSP_{0.1}$ between paper and pen, $WSP_{0.2}$ between pen and hand and the $CSS_{0.1/0.2}$ represented by the body of the pen exist. If one of these elements is not build up correctly the function cannot be fulfilled. For example if somebody tries to write on glass, $WSP_{0.1}$ does not work correctly. Reasoning on a lower level of detail it remains to clear why the function cannot be obtained. What effect prevents writing on glass? Is there not enough friction in order to turn the ball, or do the properties of the liquid ink prevent a wetting of glass through ink? Are there other reasons? To clarify such a case remains then in the hands of the designing engineer who might be given the task to create a ballpoint pen for labelling glass-surfaces.
Thus, C&CM models can be applied on different levels of detail in always the same way so that the same type of mental model can be applied at different levels of hierarchy. The $CSS_{0.1/0.2}$ of the ballpoint pen can be split up into further WSP*s* and CSS*s,* which represent the structure of parts in

relation to the structure of functions contributing to the principal function. The model can be dynamically adjusted in its degree of detail relative to the problem posed by a product.

2.2 Using the C&CM in product development

The product development process is seen as a problem solving process for design- or constructive problems. Using the C&CM is following the described general problem solving process SPALTEN [Albers 2007]. ”SPALTEN” is the German acronym for the single process steps: S - situation analysis, P - problem containment, A - finding alternative solutions, L - selection of solutions, T - analyzing the consequences, E - deciding & implementing and N - recapitulation & learning. Here we run through the phases of the process of product analysis (Figure 2).

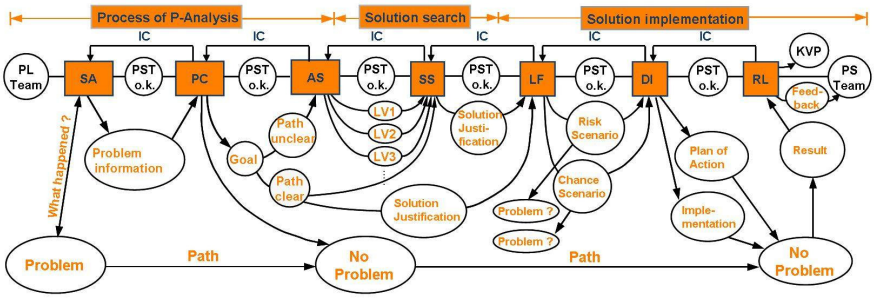

Figure 2. Model of the SPALTEN problem solving process [Albers et. al 2007]

The C&CM is used to describe the objects of the problem solving process. These objects are the relations between, on the abstract side, the functions a product fulfils and on the other side, the shape which fulfils the functions of the product.

Describing the product in terms of the C&CM then is the situation analysis and the problem containment of the problem solving process. These steps define the solution room in which new ideas for the evolution of a product are sought. Generating alternative solutions and selection of solutions then means evolution of the existing description of the product towards the intended goals. In the example of the ballpoint pen the situation analysis and problem containment results in the explanation of why it is not possible to write on glass. Having established a clear chain of causality for this cause, e.g. “the adhesive force with glass of the used ink is too low to establish a bond with the glass” opens up a solution space for searching alternative solutions. New approaches can be e.g. “Use a more adhesive ink”. The finding of solutions is thoroughly boarded by the problem description and the other way round the selection of solutions can be more easily conducted. Thus, using the C&CM based on a problem solving procedure provides a flexible support within an often unstructured creative process.

3. Solving design problems

The following sections have the goal to clarify the background in which the development of the C&CM is settled. This first section describes the product development process and its characteristics in order to explain why the C&CM is set up as a very free and intuitive way of building up a model of the objects of the product development process.

3.1 Combining new and existing elements

Product development is always a combination of new solution principles with already existing components. The previous example has shown that the analysis of the ballpoint pen leads to an eventual new and innovative writing device starting from an existing technology. If new and already existing elements are combined the accuracy of the information content of the single information fragments varies. There are facts and there are fuzzy assumptions and wishes. Sharp and fuzzy information pieces have to be handled at the same time, each with the right flair. The designers challenge is to weight each part of information in the right way so that in the end a new but to the

boundary conditions fitting solution is the result. A great danger is that designers rely on vaguely made assumptions which they put into the wrong context and which will, when the assumption turns out to be wrong or insufficiently right, endanger the success of the whole project.
If e.g. the designers start to find new solutions for a ballpoint pen which can write on glass through increasing the friction coefficient in $WSP_{1.1}$ in order to make the ball turn again and thus penetrating the glass with ink, while having not cleared the cause for the inability to write on glass the project will run at least for a certain time into a wrong direction. Time gets lost. On the other side e.g. the manufacturing process for casings of the pens or the bushing of the ball within the shaft may not changed and must be considered in any situation. Thus, the room for solutions is limited in a very concrete and precise way.
The portion of new and existing elements varies from project to project and thus makes sure that any product development project is different from the other. Thus, designers require methods and provide support the handling of the problems as they come along.

3.2 Analysis and synthesis

Finding solutions is a process of "chaos". A problem can be comprehended within all facets through generation and evaluation of solutions [Asimow 1962]. Analysis and synthesis are strongly networked parts of the problem solving process. Asimov [1962] and Simon [1969] point out that the often principally separated steps may not be split up for a complete overview. The normative procedures of the VDI guideline 2221 [VDI 1993], which represent the classical design methodology approaches neglect the interaction of analysis and synthesis. On a high level, these standards give a framework for the product development, but on a concrete working level the VDI and any normative procedure, do not support the creative, chaotic process.
The insecurity of the synthetic processes is very difficult to systematize. These processes can not be separated from the analytic ones. It is also known, that the generation of something new always requires „daring" a step into the unknown [Ehrlenspiel 1995]. The step into the unknown cannot be directed directly onto the solution as the location of the solution within the unknown area of the solution space is not known before it is found. Within product development the unknown space is between function and the shape that fulfils that function. Without an analysis of why the ballpoint pen is unable to serve writing on glass, the idea of using an ink that is more adhesive to glass would be have a huge amount of speculation. The analysis steps guide or direct the creative steps into the unknown.

3.3 The role of modelling for solving design problems

The C&CM is a model, as its name already states it. Building up models is the only means by which humans can act and interact with their environment. As we are not able to catch the complexity of the world, we produce simplified pictures of our world and relate these to the perspectives and organisations, which structure our life [Stachowiak 1973].
Models in product development representing the objects of the product development process are always generated relatively to the problem in hand. Different viewpoints of different people generate different problem representations. Basing on the knowledge about certain areas of expertise, the issue becomes more complicated when enterprises make use of the knowledge of experts stemming form different disciplines in engineering. In the author's understanding, an applicable support for the engineer, who is explicitly charged with the task to find new solutions or fixing error problems must allow the engineer to do what he wants and act in the way he/she was taught but making it transparent to his team mates.
The following is extracted from Herbert Stachowiak's "general theory of models" [Stachowiak 1973]: Insight in models and through models is always relative to determined subjects. Modelling in any case has an intention and never is aimed at insight just fort he sake of insight. Using models or modelling is selecting information for a determined intention, which is always depending from the originator or the user of the model. According to Stachowiak three general tokens brand the use of models in general:
Token of illustration: Models are ever models of something, i.e. illustrations, representations of natural or artificial originals, which their selves can be models again.

Token of abbreviation: Models in general do not capture all attributes of the through them represented original, but only those, which seem relevant to the originator and/or user of the model.
Token of pragmatism: Models are not per se clearly assigned to their originals. They fulfil their function a) for specific, cognizing and /or acting, model using subjects, b) within certain timing slice and c) under constriction of specific notional or real operations.
In the case of the C&CM, where models of the relation and elements of function and form are built up, the credibility of Stachowiak's tokens is supported through the difficult decomposition of technical systems. Asimow [1962] states, that a complex technical system is a quiet neatly decomposable system. Any designer modelling technical systems in a hierarchical manner will finish with a different representation of the product. Within the example of the ballpoint pen, any designer modelling the product will include or exclude functions, geometrical entities or influences of the environment in a different manner. One e.g. will consider the load of the user onto the ability to write on the glass as a crucial influence for the issue. Other designers already know or have the experience that the user load does not influence the writing ability at all. Thus, the model strongly depends on the knowledge and experience of the designers in charge. The C&CM can the help bring together the different pieces of knowledge into a clearly argued chain of explanation. The C&CM allows based on the few basic elements of Working Surface Pairs and Channel and Support Structure to find a common way to argue about technical problems.

4. Conclusion

The research surrounding the development of the Contact and Channel Model focuses on the thinking and acting individual who represents the value of an innovative enterprise. The knowledge and ability to use this knowledge singularly as well as in multidisciplinary development teams to solve complex design problems i.e. create new, qualitatively valuable, and successful and thus innovative products generate the advantage in the competition with other enterprises. The interacting individuals are the key to innovation. Only through the engagement of great designers enterprises will be able to create great products. The intelligence must stay with the acting individual and should not exclusively be hidden within the system [Dueck 2007]
With the Contact and Channel Model C&CM a support is provided, which in a chaotic, through multiple goals and through different procedures characterized environment of product development makes possible a systematized but free and dynamic way of modelling. Analysis and synthesis cannot be separated on the practical level. Creative steps are closely intertwined with the evaluating steps. Evaluation directs the finding of solutions. The C&CM can support on the practical level by displaying the interactions of the objects of different levels of information fuzziness.
The basic systematic of the C&CM allows everybody to use the model in their own strategy of problem solving. A common ground for argumentation and visualisation is provided, which in the end helps to focus the establishment of a clearly described and argument description of the problem and the found solutions, thus can save the time wasted for unstructured non-goal oriented discussion.
The tool of C&CM allows supporting designers in complex design projects and not the other way round.

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