WORKING SITUATIONS IN PRODUCT DEVELOPMENT: LINKING TECHNOLOGY, CONTEXTUAL FACTORS AND DESIGN TASKS

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ABSTRACT

This paper describes a framework for understanding working situations and how technology, contextual factors and design tasks can be linked in order for the product development process to become more efficient. The proposed way of achieving this is to ensure a better alignment between design goals, the underlying design process, design methods, and the surrounding contextual configuration, including technology. Engineering designers utilize and depend on design methods, design processes, other people, their physical surroundings, and different technology-based generic and engineering-specific tools, in order to be effective. Hence, they "orchestrate" the design process using the wide array of methods, tools and contextual factors that are available at their disposal. Designing the working situation in which they engage in problem setting and problem solving, can be viewed a means to improve design performance in concurrent engineering. This can be done by actively manipulating contextual factors ensuring proper alignment between goals, design methods, overall design process and contextual factors.

INTRODUCTION

The process of design can be seen as "changing existing situations into preferred ones" (Simon and Schön 1982). This definition is usually utilized when designing artifacts, but it can also be used when designing the *working situation*, where the design of artifacts takes place. Product development theory describes product development as a sequence of distinct activities. What are often described, is *what* to do, and sometimes also a rationale explaining *why* this approach is necessary or suitable. However, a detailed description of *how* to perform a design task is often omitted. While problem solving can be described as a selection from available means, the one best suited to established ends, the broader concept of *problem setting*, where the decision to be made, the ends to be achieved, and the means which may be chosen, is often ignored (Schön 1982). Similarly, the activity of formulating and debating a design problem, where knowledge is represented as an open, multi-faceted problematic, is essential in product development (Engeström 1997). In this paper the context of the problem is considered a part of this problematic. Hence, how to solve an ill-defined problem does not only depend on the character of the problem, but also on the situation in which the problem presents itself. Configuration of contextual factors in different working situations thus can be handled as a means to enhance the problem solving capabilities. This can be describes as building contextual support for different processes that occur in product development.

Designers often find themselves in situations that do not fully support the processes they are engaged in. Often there are discrepancies between the requirements of the problem and the solutions the current situation has to offer, which can reduce the efficiency of the design process. These discrepancies can be described as misalignments between goals, design methods, overall design process and contextual factors. These should all be adjusted in such a way that they are compatible with the overall goal. In these instances, it may become necessary to change the configuration of the working situation.

An example of such a discrepancy can be two designers discussing a design problem on a set of paper printouts. Without knowing it, they may be "captives" of the working situation they find themselves in. While trying to look for solutions in what they perceive as the real problem, they may neglect the contextual aspects of the problematic, as lack of larger visualization aids, atmosphere creating aids et cetera. Thus, solving a contextual problem or addressing the contextual aspects of a larger problematic by changing the working situation may reveal a more elegant solution to the a problematic than working out the perceived problem in the normal manner, or "the hard way."

OBJECTIVES AND GOALS

A design process is a very complex set of activities that are in some way related to the contextual factors of these activities. This paper describes a framework for

understanding the product development process by defining the set of different working situations in which the designer finds him or herself as the basis for evaluating constraints and possibilities in the overall design process, in addition to design activities and methods. Working situations that in some way or the other support product development and concurrent engineering in virtual teams are of special interest.

This approach will offer a foundation for a product development methodology that allows the problem solving process to become more adapted to the core design problems, better adjusted to contextual factors of the design process, and less controlled by external and internal constraints and requirements. A way of achieving this is to better understand the role of working situations, which consist of different configurations of design methods, design processes, people and technology in a physical context.

EXISTING THEORIES AND WORK

During a typical engineering designer's working day, they find themselves busy doing individual design activities on their workstation, searching for information using the web and other resources, receiving and making several phone calls, sending and receiving a number of emails, meeting with visitors in their office landscape, and interacting informally with peers and customers in project meetings. In addition, they make informal sketches on a whiteboard or a piece of paper to clarify certain design aspects, perhaps as they meet colleagues by the coffee maker. They also make presentations and collaborate with others using chat, data conferences, and then save their work in virtual workspaces in order to make their latest updates available to others that are working on the same projects. As described above, the design process is indeed very complex, and it is often difficult to categorize the different sub processes that are taking place in the overall product development process.

According to Ulrich and Eppinger, the product development process can be described as *"the sequence or steps that an enterprise employs to conceive, design and commercialize a product"* (Ulrich and Eppinger 1995). The traditional, sequential, problem-oriented approach prescribes a logical cause and effect relationship between current design problems and how to solve the problem. The essential relation is between the problem and the standard problem solving method for that particular problem or group of problems. Lerdahl has described these context free methods as follows: *"The user context is then viewed as one of many rational criteria in the specification phase. Furthermore these methods try to be independent of the context in which the product is supposed to fit"* (Lerdahl 2001). Hence, traditionally, external factors in product development have not been considered to be important. However, the product development is a very complex activity where the designer typically changes environment several times per day. The availability of tools and people, in addition to differences in the surroundings, change as the designer move from one working situation to another. Contextual factors should be treated as a mediating element in working situations. The framework discussed here suggests that the problem solving process should be a configuration of the best available problem solving methods that are properly aligned with a supportive combination of contextual factors.

CONTEXTUAL FACTORS IN PRODUCT DEVELOPMENT

Contextual factors in product development can be described as surroundings, people and technology. Different surroundings define the physical context of any design process. Different configurations of people within certain surroundings influence the way and how often we communicate with each other. Technology influences the way we perform tasks related to any design process by introducing new opportunities and new ways of communicating, exchanging and sharing information, and the way we conduct other tasks. In addition, technology enhances the functionality and adds flexibility by making it possible to perform design activities independently of time and location. It is considered necessary to gain a better understanding of the relations between the tools designers use when designing, communicating and collaborating while they are using both a main virtual workspace and various remote technologies of a supportive character.

The physical domain is strong in terms of supporting a feeling of presence and real time collaboration, and for communicating through effective, large-scale visualization and the use of body language, which can trigger many senses simultaneously. One of the most prevalent advantages of interactive surfaces in the physical domain is that the input and output surfaces are the same, and this is well adapted to the favorable process that takes place during engineering design, where the designer actively reflects on his or her own design process (Schön 1982). On the other hand, the use of virtual communication tools such as virtual workspaces and data conferencing tools increase steadily. As much of the designers' interaction with others happen through these channels, it is becoming increasingly important to position these technologies as a natural part of the physical context. This two-step process is described below:

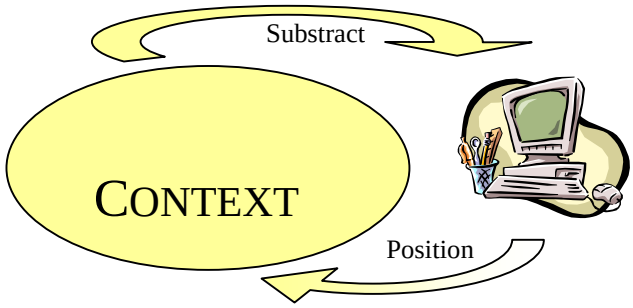

Figure 1: Linking Technology and Other Contextual Factors

1) Subtract important characteristics from the physical environment in order to create adequate functionality in the virtual workspace, and increasing the usability of these workspaces by using familiar terms and expressions known from traditional physical context, such as room metaphors et cetera. This process can be described as giving virtual

workspaces physical characteristics, and this process has been in progress for quite some time, as recent virtual workspaces usually come bundled with a wide variety of different tools.

2) Effectively position the virtual workspaces in the right context, and understanding the relations between the virtual workspaces and the environment they are operating in, or the designer interaction space. In particular, this can be accomplished by making use of technologies with combined characteristics, such as digital whiteboards that combine excellent visualization characteristics with virtual characteristics, such as the ability to share information effectively over distance, et cetera.

The physical domain is defined by the surroundings and other aspects of the physical context that encompass engineering designers. These are placed in the physical domain because of their distinct physical characteristics, by representing physical artifacts. Interactive surfaces in the *physical interaction space*, such as drawing surfaces (blackboards, whiteboards, paper, etc.) are of special interest, since these represent the points where engineering designers interact with their surroundings using pre-described, accepted methods.

Acknowledging the importance of understanding the designer interaction space is a key factor enabling the transition from physically co-located design work to effective design as performed by teams organized virtually. Improved design effectiveness and efficiency is the outcome of understanding and learning to master the opportunities prevalent in the interaction space of the designer, and understanding the role of virtual, collaborative workspaces in the context of the interaction space. The designer interaction space thus describes the system of physical context and virtual communication and collaboration components the designer interacts with, either by interaction through physical presence or through various virtual means of communication and collaboration.

WORKING SITUATIONS

Working situations describes the configuration of design methods and activities, design process, and contextual factors. These are all interrelated. Working situations occur within the framework of the designer's interaction space. Different working processes typically have different key configuration characteristics, based on external constraints and requirements and individual problem solving preferences, in addition to those introduced by the contextual factors people, technology and surroundings, which define the context of any given task-oriented working process.

The Complexity of Working Situations

Working situations are very complex of nature. The complexity of working situations is indicated in Table 1. In this table a small excerpt of the configuration variables surroundings, people, technology, process, and activities, is shown. Any configuration of these that is internally consistent defines a unique working situation. Hence, any changes in any of the configuration variables will inherently lead to a new working situation.

Table 1: The Complexity of Working Situations

Design Context: Surroundings	Office	Design studio	Meeting room	Informal zones	Travel	Home
Design Context: People	Team of One	Co-located (small to medium)	Co-located (medium to large)	Co-located with remote member	Mix of co-located & distributed	Fully distributed team
Design Context: Technology	CAD, CAE	Digital whiteboard	Telephone (mobile)	Virtual workspace	Data conferencing	Mail & messaging
Design Process	Detailed modeling	Concept generation	Analysis and evaluation	Information sharing	Decision making	Transfer of experience
Design Methods / Activities	QFD	TRIZ	Synectics	Brainstorming	Morphological Box	Value Analysis

Efficient Use of Working Situations

A new approach is proposed that is based on the use of working situations as the main perspective where surroundings, people, technology and design tasks are considered a part of the same, holistic framework, and where the significance of contextual factors are acknowledged and emphasized. Important aspects of this approach include gaining an understanding of how to make effective use of the visualization potential in active and passive spaces, how to act in accordance with people and their presence, and how to create atmospheres that support creativity and decision-making through motivation. This leads to a new perspective proposing a situation-based design where the designer actively reflects upon the different design situations he or she is exposed to.

Identifying and Configuring Working Situations

A working situation is here described as an outcome of a configuration process, where the goal is the input and the configuration process a means to achieve a favorable working situation. This is adapted to the goals, by providing appropriate design methods and a suitable design process, backed up by a supportive context consisting of a well balanced configuration of people, surroundings and technology.

When configuring working situations, the point of entry for the designer should be the goal, or what he or she wants to accomplish. This provides guidance to the design methods, the overall design process, and contextual factors. The type of process the designer is facing, whether this is concept generation, evaluation, structural analysis, decision making or any other kind, is related to both contextual factors, the overall goal, and the specific activities he or she engages in.

The designer should then move on to identify possible configurations of surroundings, people and technology he or she could choose from that would provide adequate support for the process he or she is about to engage in, and then

select the most appropriate configuration. The configuration variables of working situations are shown in Figure 2.

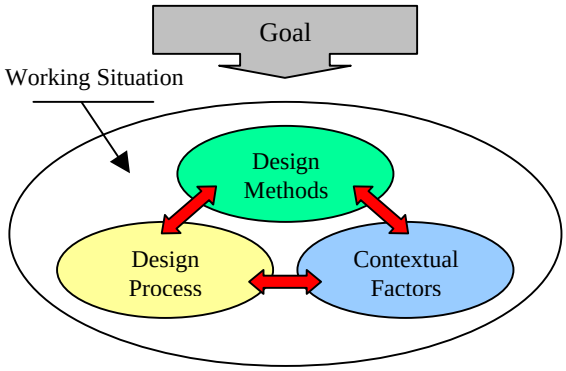

Figure 2: Working Situations, Conceptual Framework

CASE STUDY

A series of case studies in graduate course SIO2043 Machine Design and Mechatronics at Department of Machine Design and Materials Technology at NTNU (Fyhn et. al. 2001, Hildre et. al. 2000), showed that there were differences in how product development activities were carried out, depending on the working situation. Special attention was paid to contextual factors in concurrent engineering. In one of the case studies, half of the student groups were physically co-located, and the others were organized virtually, communicating through the use of data conferencing (using MS NetMeeting) and email. All the different stages in the overall product development process were observed, but special attention was paid to the creative processes, concept generation in particular. Concept generation is a very creative activity that depends on the concept of flow (Fyhn et. al. 2001). This process requires a working situation that supports this kind of activity.

Co-located Groups

In the co-located groups, the students developed concepts using PAD-techniques (Ottoson 1998), while using body language to explain and discuss ideas. The contextual configuration supported a strong feeling of presence and close collaboration. Furthermore, being co-located created an atmosphere, which supported flow. In addition, the tools in use were perceived as being transparent for the students, there were few obstacles, using them did not obstruct the flow in the creative processes. Finally, the paper-based sketches were perceived as being personal, with a strong ownership. The students in general neither drew nor wrote on each other's sketches. Instead, they made new sketches incorporating combined ideas from the group. All work had to be scanned in order to make it available to anyone, anytime.

Virtual Groups

In the virtual groups, the lack of body language, lower feel of presence and other aspects of altered contextual configuration changed the design methods in use as well as the design process. The design methods changed as the distributed team configuration required use of different tools to contribute to the product development process by communicating, or by making sketches or comments. The case study indicated that the virtual team configuration to some extent was inferior to the co-located team setting in terms of creating an atmosphere for close collaboration. In addition, the technology used by the students was not perceived as being transparent due to many technical problems. The students could often feel that the tools in use obstructed the flow in the creative processes. However, other interesting aspects were observed as well. The virtual medium used for collaboration over distance was to a much greater extent than the paper-based media perceived as being a shared medium where the students could build on each other's drawings and ideas.

There was a tendency that the working situations were adapted to fit the goals over time. At first, the teams were confused by the new, imposed working situation where they had to collaborate over distance, but they gradually learned how to master this situation. Although slow at first, the ability to make necessary adjustments in the working situations eventually improved the efficiency of the design process, as the students discovered ways to make these adjustments.

FINDINGS

In these case studies, there were strong indications that contextual factors and the way these were configured had a significant impact on both the overall design process, the design methods, and the activities the student were engaged in. The team configuration influenced the tools in use, which in turn affected both the overall design process and the different design activities.

Among the criteria that were observed, achieving a feeling of presence and close collaboration were important for the students. A team of designers needs a framework in which they can express opinions and excitement. Hence, the use of body language is important. For this process, adapting the working situation so that the contextual configuration supports the various activities taking place in the process is very important. To ensure a smooth process, it is important to make the technology as transparent as possible so that the creative process is not hampered. The surroundings, or physical environment, should be equipped with technology with required functionality. To some extent one can say that the virtual groups lacked contextual support. Hence there is a need to establish strong links between the technology in use and the context in which the technology is in use, as described earlier, in Figure 1.

It seems like the most common basis for choosing setting is habitual practice, one chooses between a set of "standard solutions" where one feels experienced. These standard solutions often represent only a fraction of the available contextual configurations. Hence, designers often get "stuck" in the wrong working situation, or there is often a lag between the change of process and the necessary adjustments in the working situation. However, over time the standard

solutions are slowly adapted to fit the problems better, in particular in terms of providing better contextual support for the design process.

CONCLUSIONS

Describing the design process through a set of working situations describes an approach for designing based on an notion that designers are present in a physical context, and that different configurations of surroundings, people and technologies can be adapted to different design methods and activities, besides providing contextual support for different design processes. These configurations each define a distinct working situation that is unique and has its own characteristics in terms of modes of communication and collaboration. The great selection of possible configurations should be used as a means to ensure better contextual support for design processes, methods and activities, which will allow the problem solving process to be better aligned with the problem setting, by taking contextual factors into consideration.

A series of case studies has shown that there are clear indications that an increased awareness of the role of working situations in product development will improve the utilization of the principles of concurrent engineering. This is particularly important for working situations dominated by real time collaboration.

In order to make use of configuration of working situation as a design tool, there is a need to make contextual factors tangible and for reaching a deeper understanding of how contextual factors relate to the design process and the design problem itself. Once this is established, the reflective designer can become capable of monitoring his or her own design activities in such a way that a feed forward approach is made feasible. This can be described as "The best working situation is always the next", where the designer actively navigates through different working situations instead of drifting between them, which is the logical outcome of not taking contextual factors into consideration.

FURTHER RESEARCH

Suggestions for further research include defining a framework where the contextual factors are made tangible. There is also a need to establish a set of criteria, which can serve as guidelines for configuring working situations. Combined, it is then possible to make tools and methods for configuring suitable working situations as a function of goals and available activities, processes, and contextual configurations.

Furthermore the dynamics of working situations should be explored, in order to understand the transition mechanisms between different working situations and how to avoid the lag or delay between the point where the working situation does not provide sufficient contextual support, and the point where the designer discovers this, and decides to make the necessary adjustments by configuring a new working situation.

It would also be useful to explore tools, methods and technologies that can assist the transitions between different working situations, making it easier to move a product development process from one working situation to another, without losing momentum.

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BIOGRAPHY

KJETIL KRISTENSEN was born in Bærum, Norway. He received his graduate degree (sivilingeniør) from the Faculty of Mechanical Engineering at the Norwegian University of Science and Technology in March 2000, specializing in product development and distributed collaboration. He is currently pursuing a dr.ing. degree at the Department of Machine Design and Materials Technology at NTNU. He is also a co-founder of Boost Communications, a company offering SMS-based marketing tools and communication solutions for businesses and organizations.