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Towards Collaboration in Engineering of Tomorrow – Building highly interactive Distributed Collaboration Platforms

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ABSTRACT

This paper focuses on the product development process. It analyzes state-of-the-art collaboration workflows, and industry-standard collaboration tool functionalities. It then compares these with new tool and process concepts from industrial and academic research and development. New concepts of user-interaction are introduced, which will allow the linking of virtual and hardware prototypes collaboratively in a mixed-mode, for project reviews. The “virtual co-location” concept is explained based on several use-cases derived from the cross-functional development of mechatronic systems. Furthermore, based on business case analysis from real distributed development projects, it explains why there is a need in the automotive industry to further explore advanced technology solutions for collaborative product development.

INTRODUCTION

In the Automotive industry, the level of complexity of premium products has tremendously increased in recent years by the integration of new bus systems, new system functions (primarily in electric/electronics) and new materials. Furthermore, today’s cars are highly sophisticated mechatronic systems, requiring development and integration partners to increasingly work together as distributed networks of experts, since knowledge does not necessarily coincide with physical presence. New ways of communication must be found, and they depend heavily on new functionalities in IT-based collaboration tools.

Collaboration support is required across the complete lifecycle of a product, starting from the generation of first concepts until product recycling. As different domains such as project management, product engineering, software engineering, systems integration, product testing, preparation of vehicle production launch as well as product service need to be covered, the requirements for future collaboration scenarios are diverse and currently not met by a single tool. However, they can be integrated into a collaboration platform concept which we call “virtual co-location”.

According to Grabowski et al., [1], and to common understanding, a complex task such as the development of a mechatronic system needs to be subdivided into subtasks (referred to as simultaneous or concurrent engineering) to be successfully undertaken. However, within this original concept, the interdisciplinary work and thus communication and collaboration between the workgroups are not yet integrated. In fact, since the system is decomposed, it is treated as a complicated system, not a complex system, and the interdependencies between the subtasks are either ignored or neglected.

In the industrial world, CAD (design), CAE (analysis and simulation), CASE (software engineering) systems are traditionally used by very different expert groups involved in the development task. Emerging Collaborative Engineering Portals enable collaborative project work between geographically distributed teams and bring multidisciplinary teams closer together actually enabling the sharing of data. To this end, the concept of a Virtual Project Space as an integral part of the BMW-Group Partner Portal is currently being developed at BMW and has recently entered the pilot stage.

This pilot installation resembles in many respects the "State of the Art" collaborative IT-solutions available on the market today. It can be well regarded as a first step towards an even further reaching distributed collaboration platform, which will become increasingly interactive over time.

In Figure 1, the original distribution approach described above only provides horizontal work- and information flows, while complex products also require a vertical collaboration aspect among the individual groups or persons. This vertical integration, this management of interactions among subtasks is becoming more important as global competition grows and product performance is pushed at the expense of size.

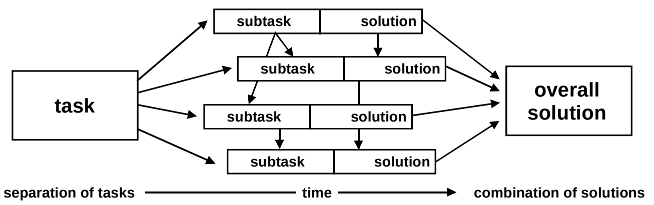

Figure 1: Several groups working on a common task.

The task is complex enough for interdisciplinary teams at a collocated geographical location. It seems a daunting, almost impossible undertaking for net-based teams. This difficulty has to be overcome for today's complex mechatronic products, and even more for the integrated systems in tomorrow's cars. The required knowledge is spread all around the world and needs have the ability to be combined in collaborative team processes.

According to Desanctis and Gallupe [2], there are different categories of collaboration that can be considered as time or space dependent as shown in Figure 2:

		TIME	
		Same Time	**Different Time**
SPACE	**Same Place**	– Electronic Supported Meeting	– E-mail – Document management systems – Web-based team/project rooms – Calendar and scheduling systems – Workflow management systems – Electronic bulletin boards
	Different Place	– Audio conferencing – Video conferencing – Data conferencing – Instant messaging – Desktop conferencing	– E-mail – Document management systems – Web-based team/project rooms – Calendar and scheduling systems – Workflow management systems – Electronic bulletin boards

Figure 2: Time/Space taxonomy of group processes[2].

Today, mainly asynchronous collaborative work is performed. However, efficient teamwork is stimulated and strengthened by synchronicity, e.g. by gaze awareness, intuitive system interaction, simultaneous interaction capabilities, etc. Current collaboration tools do not practically and effectively meet these requirements and are thus rarely used for net-based teamwork. In particular, the early stages of the product development process (PDP) are still performed "traditionally" on paper and with physical presence, although prior and subsequent steps are already performed digitally, as shown in Figure 3:

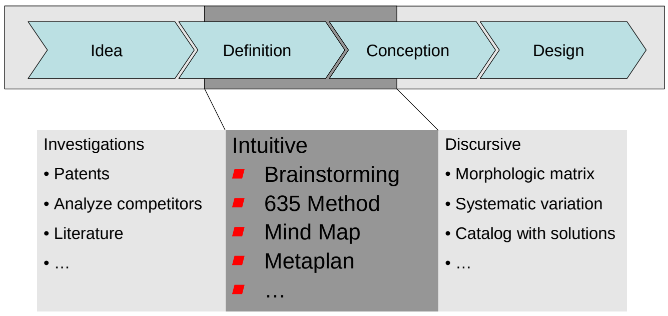

Figure 3: "Analog" part in the PDP.

In order to bring together people and knowledge, new ways of communication must be developed. These depend heavily on new functionalities in IT-based collaboration tools.

It is important to note that Engineering Portals are used much more widely in larger companies, mainly as a data source or a data container for many aspects (engineering, planning, manufacturing, finance, bill of materials, suppliers, …). Their role is critical and very important. However, real creative work is not done via a portal. Furthermore, videoconferences still lack the integration of discussion support components to be used beyond just seeing the person you talk to. Therefore there is a need to investigate novel methods that become enablers for the collaborative systems of the future.

There is a growing number of joint product development projects between OEM's and also between OEM's and engineering service providers, where not only components but whole vehicles are jointly developed. This creates the need to integrate processes and IT systems in collaboration platforms that are supported by engineering portals and interactive communication tools. This implies also new organizational concepts for a virtual engineering community [19].

LITERATURE REVIEW

Full integration of human collaborators in a virtual environment is still an unsolved problem [11]. Combining different technologies like video capture, motion tracking, geometry generation and steering is a very challenging task. There is a trend in this field of research towards visualization of participants in a virtual environment using video.

In some VR applications, the faces of the participants are displayed on virtual screens as in a video conferencing system [12]. Here, the separation between the representation of the participants and objects interferes with the visualization of their direct interactivity.

The use of virtual screens can be avoided by uncoupling the video texture of the participant from his background. A method frequently used for this purpose is the blue-box technique: the background is of a defined color, and an algorithm can decide which pixels of the image have to be translucent. The disadvantage of this method is the effort required to surround the user with the blue background. One example of this technique is an off-line video capture method in which a person stands on a turntable in front of a blue screen [13]. One 360-degree revolution is recorded by a video camera. The images are stored permanently, and then selected within a VR application depending on the other participant's point of view. The main shortcoming of this method is that the current movements of the users, for instance gestures or mimics are not depicted. A second example using the blue-box technique was developed by Van Pernis at Clemson University. He fixed a camera on a Head Mounted Display helmet, filming his hands in front of a blue background and superimposing the picture on a virtual environment [14]. At the University of North Carolina, a user surrounded by a blue background was filmed from 6 points of view [15]. Hardware accelerated texture projecting was used to project the image within a visual hull. Klar [16] used the method to develop a design environment entitled virtual Lego©. In it, using an Immersadesk®, and a camera placed next to the user where another collaborator would have been standing, a picture of the hands of the user are taken after projecting a blue image on the table for a fraction of a second. The picture is then sent to the remote site and merged within the CAD environment used. The same setup is mirrored so that both users see the other partner's hands as if they are collocated. The shortcoming of this approach is that only the hands of the users are transmitted real time, no facial expressions are available. An advantage is the very small amount of information transmitted.

Finally, the Blue-C environment mentioned earlier [11], has a set up in which the participants are captured real time using 16 cameras located around a cave with transparent/opaque walls coupled to the VR glasses. The setup allows the capture of complete humans and their transportation to the remote site. The quality of the image is still a bit poor, but the technology has been proven.

VIRTUAL PROJECT SPACES AND PORTALS

One of the biggest driving forces to develop the concept of a Virtual Project Space was the desire to reduce the number of so called Resident Engineers on site at BMW. Today, Resident Engineers coming from BMW`s suppliers work closely together with BMW-engineers on the very same office floor. This way, Resident Engineers have undisturbed access to all applications and data like BMW-engineers to perform their tasks [17].

At the very moment in which a Resident Engineer shall participate in the product development process remotely from his own company's site he has no access any more to BMW`s applications and data (see Figure 4). In order to enable access again, BMW has developed the BMW Group Partner Portal and put into productive use. This portal is an example of a B2B portal that can be regarded as an engineering portal that grants access to partner engineers based on security mechanisms like authentication and role-based authorization.

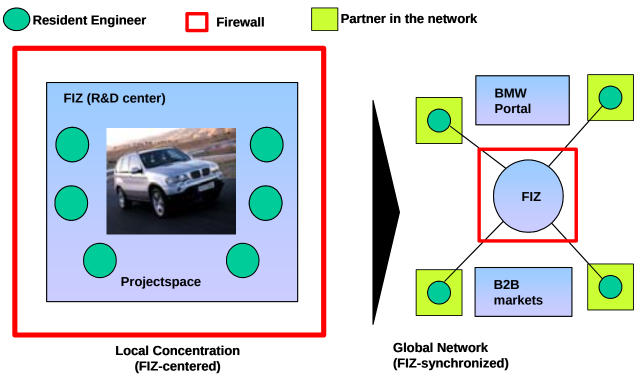

Figure 4: Towards distributed engineering teams.

However, today the BMW Group Partner Portal does not convey the idea of being inside a project context or being a member of a "virtual team" once the user is authenticated and authorized to use certain applications by which he can manipulate data. In order to enhance the Partner Portal by adding a project context we first did an in depth analysis of the setup of physical project spaces at BMW [18]. The findings can be summarized and depicted in the following Figure 5:

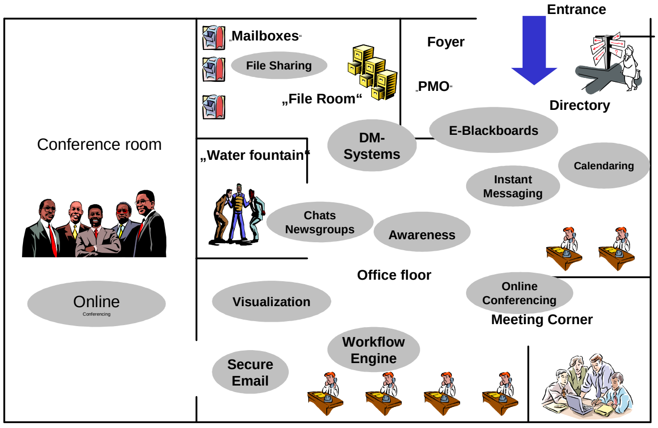

Figure 5: The blueprint of a Virtual Project Space and its software components.

The blueprint shows the functional aspects of a real project space and how they could be implemented by software components (grey ovals).

Essentially the Virtual Project Space is the replication of a real project space by means of information technology in order to bridge spatial and temporal gaps between partners within a distributed collaboration network.

The Virtual Project Space is currently been implemented within the BMW Group Partner Portal based on the software “Teamcenter Community” by the company UGS (see Figure 6 and Figure 7)

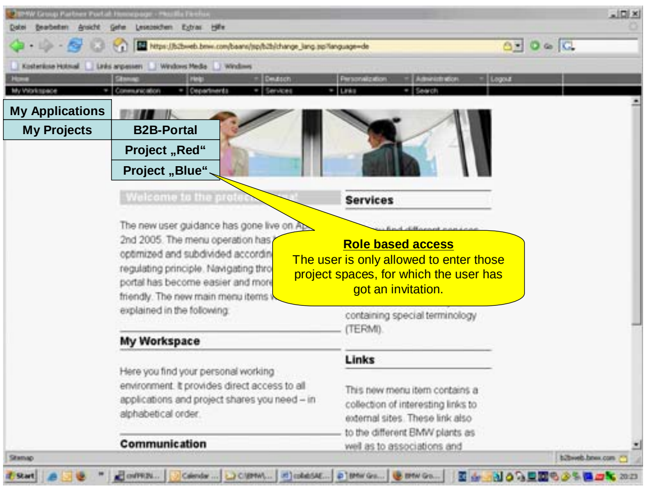

Figure 6: Integration of Virtual Project Spaces into the BMW Group Partner Portal.

“Teamcenter Community” builds upon Microsoft`s “Sharepoint Services” adding special enhancements for collaborative engineering. This software architecture allows for a modularized approach so that individual virtual project spaces can be tailored to the specific needs of a project.

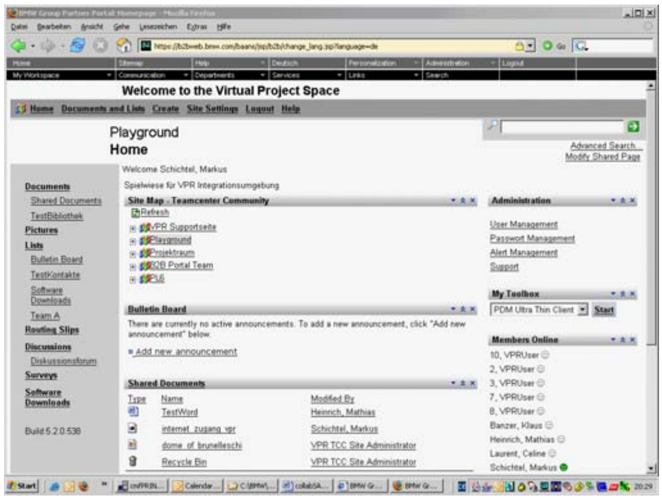

Figure 7: The “Foyer” of a Virtual Project Space.

Modules (so called Webparts) can either be pulled out of the repository of “Teamcenter Community”, bought from third party software vendors or individually designed to precisely meet the specific requirements of the processes needed in a distributed collaboration network.

FUTURE COLLABORATIVE SYSTEMS

In order to enable an efficient net-based collaboration, a virtual collocation with a clear focus on product development is required. Such an environment should not only support virtual, but also real collocation and a smooth transition between at least two worlds. It should allow hardware in the loop setups, and the ability to diagnose the functions of complex systems. In the ideal case, the users should not feel as if they are collaborating, rather they should basically be working as an individual, a well tuned collocated team, using all the tools at their disposal. One of the main aspects in this context is not only to share data between co-located partners, but also to fully integrate the human being into this environment.

The first attempts we know of, at creating such an environment for design, are described in [3]. The authors report on an implementation of a system to perform a fully immersive team session, integrating humans into virtual environments, as shown in **Figure 8**. Note that many other uses of Virtual Reality have been published that address some of the functionalities of the complete immersive environment we envision, but to our knowledge, no one has dealt with the complete problem so far.

Figure 8: First approach of integrating humans into a virtual collaborative environment [3].

One of the technological challenges we foresee, is to perform simultaneous projection and picture acquisition through a screen. Based on this technology, further development aimed at realizing a virtual collocation must be undertaken. This setup must be usable in many different stages of the PDP, starting from creativity sessions and spanning the whole development cycle up to design reviews. Unlike the applications in [3], the focus must be put more onto interaction than on a three-dimensional representation of the net-based collaboration partners. To this effect, much of the research on immersive virtual reality comes to bear.

Generalizing a typical collaboration environment, there are typically horizontal and vertical interaction workspaces, such as tables or whiteboards. During brainstorming sessions for instance, people are simultaneously interacting on these workspaces. They use well-known interaction patterns like pencils, erasers, rulers, etc. In addition, team members unconsciously stimulate each other by transmitting and receiving so-called meta-information like eye-contact, postures, etc. According to Short, Williams, et al. [4], the principal function of the visual channel in communication is to provide feedback of interpersonal attitudes, characterized as a direct expression of one's attitudes and unconscious feelings. Video conferencing technology opened the visual channel for distant communication. The importance of eye contact in the context of video conferencing has often been discussed. According to Kobayashi and Ishii [5], people feel it difficult to communicate when they cannot tell if the partner is looking at them. Eye contact plays an important role in face-to-face conversations because "eyes are as eloquent as the tongue". Acker and Levitt [6] showed in a negotiation experiment that eye contact within video conferencing increases satisfaction. Eye contact allows people to evaluate more confidently their counterparts, and to participate more comfortably in exchanging information.

Based on the technology of [3], a system that allows image acquisition through the screen together with a back-projection on it was developed. As shown in **Figure 9**, our system – the so-called 'HoloPort' – allows a typical conferencing scenario in a virtual co-location.

Figure 9: Networked group discussion using two HoloPorts, one for each group.

The tables are both placed adjacent to the HoloPorts' screens to give the conferees the sensation of sitting virtually at the same conference table [7].

Since the camera is camouflaged behind the screen, the users are not disturbed by this "electronic eye" anymore. They have the possibility now to directly look at the other team-member and thus have full advantage of the above mentioned meta-information.

In a next step, the set-up was used to allow a virtual collaboration and co-location in a team session (see **Figure 10**). Here, it is necessary to interact on the screen, doing typical brainstorming work (left) or redlining on existing parts (right).

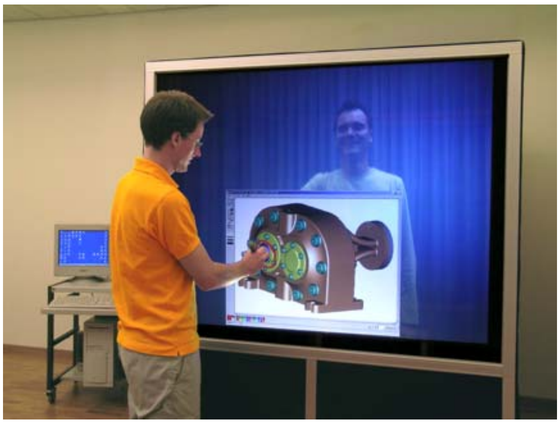

Figure 10: Working on vertical interaction space.

Finally, the virtual collaboration platform was supplemented with a horizontal interaction space. Again, a creativity session is used as a typical example for collaborative work between persons being physically in the same room, but also with net-based team members. Within such a meeting, ideas are sketched or written down and the individual work is alternating with teamwork. Both kinds of work have in common, that writing or sketching is required, independently of the creativity method used [8]. The term “creativity method” defines all principles, rules, and methods, which replace the passive waiting for ideas. Creativity methods thus enhance the probability to find good ideas and solutions to given problems [9]. We evaluated the suitability of numerous methods for digital support [10]. Comparing the different methods, the following conclusions can be drawn:

- The record card is the main element of most analog creativity methods. It can have different sizes, shapes, and colors. The team members write on it with pencils or manipulate it using other devices. Thus, a digital representation has to include the record card functionality. Digital record cards can be edited consecutively, e. g. by the session’s moderator, or they can be edited in parallel, e. g. by the team members writing or sketching on the record cards simultaneously.
- Independently of the creativity method used, the same functionalities are desired. In particular, the generation, manipulation, and the structuring of record cards are basic elements of a creativity session. This holds true under the assumption that all forms used during a creativity session are a fixed constellation of record cards. This assumption allows, in combination with context-depending communication, to simulate almost any creativity method. Thus the goal of a digital support for a creativity session is to represent the record card as a basic element. The more the handling of the digital record cards corresponds to the handling of analog record cards, the better both variants fit.

Based on this conclusion, a system that supports local and net-based teamwork as well, allowing simultaneous writing and sketching (see **Figure 11**) was realized.

As a first proof of concept a small application was realized, in which the users were asked to solve a small problem by just writing and sketching. First tests of this “creativity session” of a collocated team showed very promising results. It also turned out that a large number of pencils with different colors are not necessary, but two or three colors are sufficient. However, there is a need for other dedicated devices like erasers, markers, or reminders. Thus, further work will concentrate on supplementing this environment and on implementing these new technologies into industrial business processes.

Figure 11: Collaborative horizontal interaction space [20].

NEED FOR NEW COLLABORATION METHODS IN AUTOMOTIVE PRODUCT DEVELOPMENT

BMW is applying virtual distributed collaborative product development concepts already in a multitude of vehicle projects. The first project where distributed collaborative development has been applied was the X3 project (see Figure 12).

Figure 12: The BMW X3 is the result of en engineering collaboration between an OEM and an engineering service provider.

There is a general trend, especially in the premium automotive segment, towards stronger product differentiation resulting in the development of more model variants and derivatives. The main reason for this trend is to be more responsive to market requirements. However, as development resources are limited and are causing high fixed cost, OEM's are trying to be more flexible to market opportunities and to reduce financial risks at the same time by starting collaborative vehicle development projects with other OEM's or engineering service providers. At BMW the first example of such a vehicle project has been the X3 which was jointly developed together with Magna Steyr Fahrzeugtechnik. But there are also an increasing number of other projects where major vehicle components are developed collaboratively between OEM's. The most recent example for such a development at BMW is the new engine generation for the Mini, which has been co-developed together with PSA.

BMW has gained a lot of experience about critical success factors in an engineering collaboration in the X3 project. One lesson learned has been to address IT issues as early as possible in the due diligence process as they are crucial for the quality of the collaboration and the implementation of processes and workflows. Quite often there is no time to develop new collaboration systems during the development partnership and each partner has a tendency to fight for the use of his tools and processes. In a typical OEM-supplier relationship, the OEM can force the supplier to use his tools and systems. This relationship is more difficult between two OEMs, and the common use of standards and standardized tools becomes very important. In the BMW X3 project major challenges in the collaboration were risks in IT-security and the access of proprietary IT-systems by external users (role-based access). In the meantime, these challenges were addressed by the development of a secure engineering portal, where different models for the needed roles and rights management are implemented. The possibility of customizing an engineering portal for a virtual team that deals with a specific vehicle project, and has specific needs to access systems and data, has been described above. Nevertheless, there is a need for collaborative methods that lead to more team interaction and can already be applied in an earlier stage of product development. Several examples have been given above. Virtual team interaction will create more trust among the virtual team members and the collaboration tools will not be regarded as OEM-specific but as jointly used tools. It will be easier to jointly further develop the collaboration methods and the tools itself.

FUTURE COLLABORATION SCENARIO

Existing Virtual Project Spaces mainly consist of a portal-like environment, which can be accessed by individual persons. Thus, these spaces have the character of information systems that allow access and entry of relevant data for the product development process. However, today's spaces do not support a collaborative team session. Although they might already include a videoconferencing setup, they do not provide any intuitive handling of the system, which is particularly important for brainstorming sessions and design review meetings.

In a future collaboration scenario, an interdisciplinary team first generates ideas on a new product by simultaneously writing and sketching on a common virtual workspace. Such a development scenario could be for instance in the development of a new car seat. The seat is a mechatronic product, consisting of mechanics, electronics, and signal processing / information technology. Furthermore, it has to be integrated into another mechatronic product, namely the car.

Experts from different disciplines altogether generate the first ideas on a new product, stimulating each other, and taking into account different aspects from the very beginning. The complete team is able to write and sketch on a common workspace and thus is able to generate a common understanding. The mechanical design, the electrical circuits, or first flowcharts of the control software can be realized simultaneously, as it is typically envisioned within simultaneous engineering.

Although the team members are distributed all over the world, the collaboration environment provides the feeling of 'virtually being there', allowing gaze awareness, intuitive interaction, and other aspects, which people are used to from meetings with physical presence.

CONCLUSIONS

This paper shows the rising demand for collaboration in teams due to the increasing complexity of mechatronics products. Interdisciplinary and globally distributed knowledge requires that net-based teamwork can be performed in so-called Virtual Project Spaces. These Virtual Project Spaces, parts of Engineering Portals, are emerging as platforms to support Collaborative Engineering in the automotive industry. This concept may be very well regarded as a precursor of the various approaches of future collaborative systems presented in this paper.

The system introduced in this paper contains new modules, which in particular support the net-based collaboration in the early stages of the PDP. The paper introduces the first prototypes that allow teamwork in a more natural way than with today's commercially available systems.

After introducing the field, in which a virtual collaboration is already applied, the paper concludes with an outlook on how new technologies may be used in future business processes.

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