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# COMPUTER-SUPPORTED ENVIRONMENT FOR CREATIVITY PROCESSES IN GLOBALLY DISTRIBUTED TEAMS

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## Abstract

Today's products are characterized by an ever-increasing amount of complexity and multidisciplinarity. Companies, focusing on their core competences, face that problem by an increased amount of interdisciplinary work between internal and external partners. This global product development results in a large effort for traveling and thus increases the product development time and costs. Since there isn't any technological means that satisfactorily fulfills the requirements of a synchronous, net-based teamwork, this paper shows a first attempt so solve this problem. Beside the usual video and audio connection between networked partners, it is also possible to simultaneously write and sketch on a common workspace, integrating also the collocated partners of a session.

*Keywords: Collaboration, CSCW, Virtual Teamwork, Product Development, Creativity Method.*

# 1. Introduction

The integration of a rising amount of functionalities into a limited space leads to the development of mechatronic products and thus to the need of collaboration between different disciplines. The increasing competition between companies forces them to concentrate on their core competences. This discrepancy between the integration of different disciplines into a product and the companies' specialization onto core competences is solved by an intensified collaboration between companies. However, not only collaboration with external partners is required, but also an internal collaboration between different teams is required, in particular, if the company is a global player. The collaboration is part of a parallel working method, also known under the name "Simultaneous Engineering" (see Figure 1).

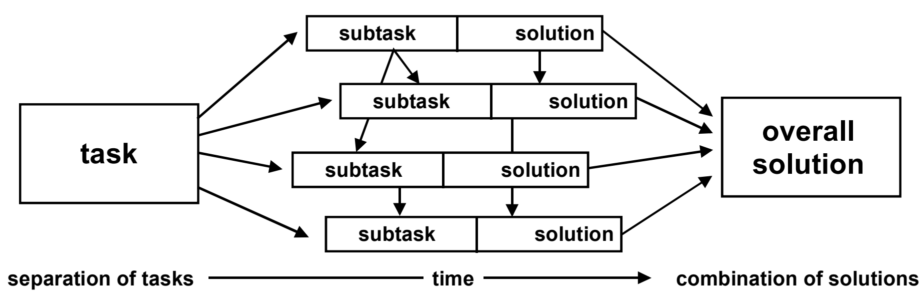


Figure 1. Simultaneous Engineering [1].

In addition to [1], the image was extended by the fact, that also within simultaneous engineering a collaboration and communication between the individual groups is required, which can be supported my means of information technology (IT).

Multiple IT-tools already exist in the geometry definition phase of the product development process. However, the early stages of product development are still performed very traditionally [2]. Although these early stages contain a lot of vague information, questions on the spatial shape of a product arise [3]. Human beings live in a three-dimensional world and also integrate this circumstance into the product development process. The typical complexity of the development process requires, that creativity and the internal processing of information (normal thinking process) are enhanced by additional external processes and media like sketching, writing, modeling, gesticulating, talking and other technological means. The human being uses these tools to articulate and visualize his ideas to a given problem, thus improving the overall quality of a solution without increasing the required time [4] [5].

For these external processes the developer uses physical and virtual models as well as hybrid forms. Typical physical realizations are sketches or drawings as well as physical mockups. With the attempt to shorten the complete product development process, more and more the information technology is involved and thus also technologies of virtual reality. However, this does not hold true for the creativity processes. Here, no suitable solutions exist and thus these processes are still performed paper-based.

## 2. Motivation

We see, that the users' simultaneous interaction on a common workspace is crucial for the generation and filtering of ideas during meetings within the early stages of product development. This interaction is the only possibility for the team members to intuitively sketch ideas and explain them to the others. By passing around one single pencil or other interaction device, a lot of verbal communication is required for organizational purposes and thus the discussion on the solution and on the development of a new product is affected. In addition, the problems remain, how the analogue solutions can be digitized afterwards without loosing information. The today's solution by photographing the paper-based results is not satisfactory

Very often the term "collaboration" is wrongly used for the fact that results are presented to a group. For that reason, there are a lot of solutions available to support presentations, also over a network. However, there are almost no solutions available for collaborative creativity processes, in particular, if some team members are not at the same location as the rest of the team. This results in minimal (and very often unusable) solutions like simple videoconferencing with integrated whiteboard functionality. The following two ways of collaboration contain a large potential for creativity processes, but where not supported by technological means so far:

- Collaborative work in a collocated team.

  Following the requirements from the above, this way of collaboration requires interaction spaces for a simultaneous interaction of all team members. Horizontal (tables) and vertical interaction spaces (blackboards) are required as well. Especially for the simultaneous interaction on these interaction spaces there is no tool available on the market, which supports the simultaneous input of multiple users. The available presentation tools are not suited for collaboration. Thus a simultaneous interaction of multiple users is not possible, yet.

- Collaborative work in a distributed (networked) team.

  Collaboration in a distributed team requires a lot of different interaction channels. One basic principle of a team session is the fact that the team members inspire themselves. Thus it is important that the so-called Meta information (the information, which is not consciously expressed by gestures, mimics, etc.) can be transferred without any losses by the used information technology, e.g. by the audio and video channel. A new system now extends a collocated team by additional members, which join the session over a network. Also for this situation, as it often appears in globally distributed teams, none or only few tools exist. Due to their complexity these tools are not used in net-based creativity sessions.

Since decisions in the early stages of the product development process have far-reaching consequences, new systems for supporting these decisions become more and more relevant. One reason for this is that the results elaborated in a team session have to be digitally provided to other business processes in a very short time. Another reason is that the team members, who are distributed over multiple locations, must be able to collaborate efficiently, almost like being physically there, when designing new complex products. They have to perform typical engineering tasks, e. g. concept studies, requirements lists, system integration, tests, etc. [6]. Without these new collaboration tools the close collaboration between engineers only would be possible with many iteration steps by asynchronously transferring all project data between the distributed team members [7]. By using new collaborative development tools instead, the slow iterative development process can be replaced by a faster interactive process.

# 3. Contributions

In this paper a system is introduced, which supports the collocated and the net-based collaboration of small groups. The system does not only support simultaneous work of collocated team members, it is also possible for virtual team members to share the common workspace for collaboration. Due to audio and video facilities all team members can hear and see each other and thus the transfer of Meta information has been improved. The system is an attempt to extend a meeting from a locally constraint room to a virtually unconstraint space. In a first realization stage, the system allows common sketching and drawing. First, the situation is realized, in which all persons are collocated and are working simultaneously on the same interaction space. In a next step the situation is realized, in which also net-based team members can join the meeting.

## 3.1. Collaborative Work in a Collocated Team

A creativity session is used as a typical example for collaborative work between persons being physically in the same room. Within such a meeting, typically ideas are sketched or noted down and the individual work is alternating with teamwork. Both kinds of work have in common, that writing or sketching is required, independent of the used creativity method [11]. The term "creativity method" defines all principles, rules, and methods, which replace the passive waiting of ideas. Creativity methods thus enhance the probability to find good ideas and solutions to given problems [13]. We evaluated numerous methods for their suitability to a digital support [14]. Comparing the different methods, the following conclusions can be drawn:

- The 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 card functionality. Digital 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 cards simultaneously.

- Independent of the used creativity method the same functionalities are used. In particular, the generation, manipulation, and the structuring of 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 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 card as a basic element. The more the handling of the digital cards corresponds to the handling of analog cards, the better both variants fit.

For that reasons the system introduced here mainly focuses on the handling of cards, on pencils and other interaction devices, as it was already done in a workplace for smaller groups [8]. Within this system the pencils were distinguished by colored light emitting diode (LEDs), which were activated as soon as they touched the surface of the workspace.

The experiences gathered with that system showed that an intuitive work is possible. Motivated by that experience, we kept the basic idea of the pencil. However, the further development of this idea should allow a larger amount of interaction devices, each of them also offering a larger amount of functionalities. More functionality also requires a more sophisticated user interface. Thus the new system cannot only recognize a simple left mouse click, it also recognizes the hovering of the pencils over an object, and it allows addressing context-sensitive menus with a right mouse click. These additional functions and also the larger amount of different devices cannot be realized anymore by different colors of the LEDs. In order to fulfill the additional requirements, the principle of the optical signal transmission was modified.

The basic idea of the modified system consists in using pulsed (coded) light, which is detected by a camera. It carries the encoded address of the pencil and other interaction devices, as well as additional functions. The principal set-up of the system is shown in Figure 2.

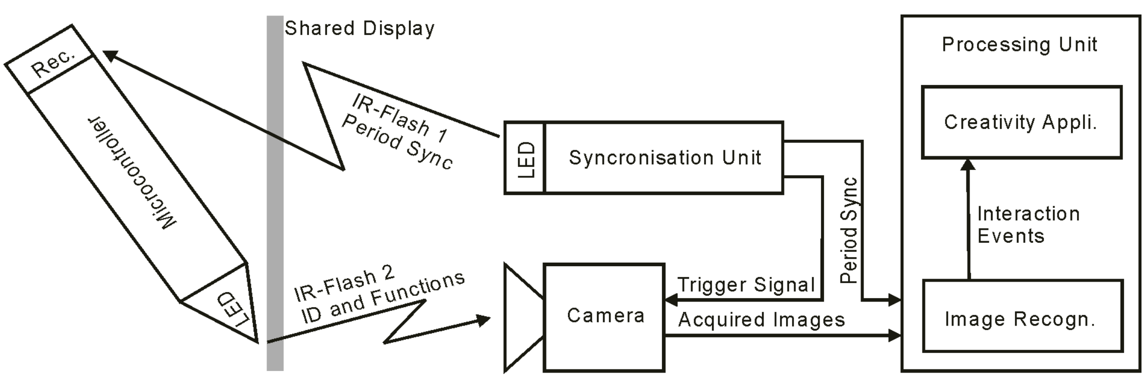


Figure 2. Principal set-up of the system.

A central synchronization unit optically transmits a triggering signal to the devices (pencils) in order to address and to synchronize them. The devices respond with a defined bit sequence. This sequence contains the device's identification, but also the information about an additional function activated by the user. The camera is also triggered by the central synchronization unit and recognizes the bit sequence, assigning it to the place where it was detected. Next, the information is given as interaction events to a creativity application. The maximum processing speed strongly depends on the framerate of the camera. First tests at a frame rate of 30 Hz did not deliver satisfying results. Due to the low frame rate of the camera detection errors occur, which were irritating during sketching. However, this problem was reduced by using a faster camera.

Unlike with the system described in [8], infrared diodes were used instead of colored LEDs. This guarantees, that the camera cannot be blinded anymore by hotspots and reflections resulting from the projection. A special infrared filter blocks any non-infrared light and only the devices are visible to the camera. Using infrared light for triggering the devices as well as for their response has the benefit that it cannot be seen by the user. Thus, no irritating light points occur (as it was with using colored LEDs) when writing onto the common workspace. In order to avoid any interference between the triggering signal for the devices and their response signal, the infrared signal uses different wavelengths and pulse frequencies.

The electronic components, which are required for the electronic encoding of the devices' addresses, are available as so-called SMDs (Surface Mounted Devices) and thus allow the design of very compact interaction devices. The pencil's tip has an IR-receiver for receiving the triggering signal. Basically, every pencil has the functionalities "Hover" and "Write". In addition, it is possible to encode three additional buttons, which represent additional functionalities of the interaction device. The devices can be distinguished from the system by their different bit sequences in the optical response signal. Pressing the tip of the pencil onto the surface activates a micro switch, which switches the integrated electronics to change a certain bit in response signal. A prototype of a pencil is shown in Figure 3.

Figure 3 Prototype of the pencil

With the technology described in the above it is possible to simultaneously detect multiple pencils, digitally representing different colors or different line widths. However, it is also possible to detect other objects, which are typically used for team sessions, such as eraser, ruler, tape, etc. This allows handling the computer very intuitively by typical objects from daily life, without noticing that these devices input now an underlying IT-system. The user already knows the functionality of each object and thus there is no need anymore to learn the system and the underlying software. All hardware components like beamer, computer, camera, as well as other peripherals were integrated into the set-up of Figure 4.


Figure 4. System used for collocated creativity processes.

Using the interaction devices described in the above, multiple users can simultaneously interact on a common workspace. However, this raises the problem, that operating systems like WindowsXP provide only one single event stream to the running applications. If multiple mice, tablets, or other devices are used, they would appear as one single input device. This requires to detect the different devices within the application layer and also to reimplement the complete event handling on the same layer. The same holds true for the graphical interaction elements (widgets), since they are also designed for an interaction by only one user. This makes it impossible to detect for example, which user presses a button or selects a menu. Thus, also the graphical interaction elements have to be developed for a multi-user interaction.

In order to solve the above requirements, modular software was developed, which is based on the platform Flash MX and Flash Communication Server MX [9], [10]. This software has a wide distribution, e. g. the client is already installed in standard browsers [12] and it is not depending on a specific operating system. Thus it is possible to run the application also on non-Windows platforms, e. g. on PDAs or some cellular phones. In addition, Flash uses vector graphics and thus has optimal prerequisites for realizing graphical user interfaces and for writing and sketching applications.

When realizing the software, we followed the idea of the digital card, mentioned in the above. Using different Flash components, multiple modules (cards) were designed, which can be used to support different creativity methods. Typical components are base cards or whiteboard cards. Also user modules with audio, video, and additional information are available. The system has been completed with components like session recorder, session player, or by the multi-mouse component, which is required for a collocated simultaneous teamwork, using multiple interaction devices at the same time. Figure 5 shows possible configurations of the user interface. It has to be noted, that due to the modular software the user interface can be configured in any context. Thus, the user interface can be adapted to the available hardware. In the left part of Figure 5, a typical user interface is shown for an environment with only one single interaction device, like for instance the stylus of a tablet PC. The functionality of this stylus has to be defined prior each action. In the right part of Figure 5, a typical user interface is shown as it would look like if multiple interaction devices are available. In that case, the user changes the devices' attributes by changing the device itself, e. g. changing from a red to black pencil or to an eraser. This is the normal behavior, as the user would work with an analogue technology and thus the most natural support of a creativity session.

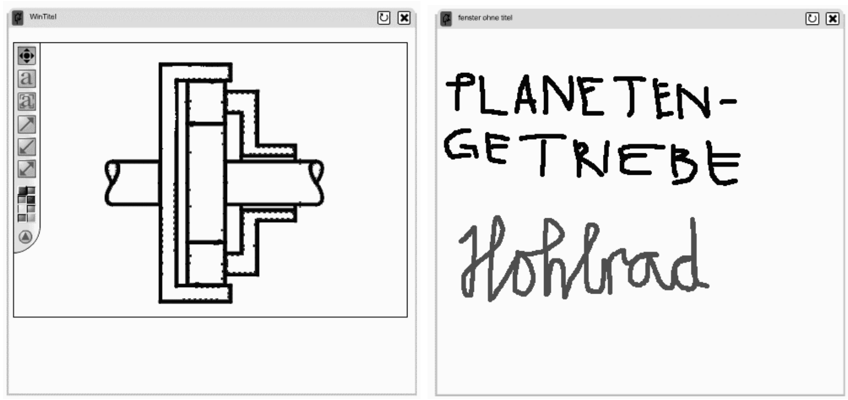


Figure 5 Different configurations of the graphical user interface (GUI).

## 3.2. Collaborative Work in Distributed Teams

The system becomes more complex, if not all team members are physically present but connected over a network. All team members have to work on the same workspace, but also have to see and hear each other over an audio and video channel. Thus, the workspace has to be enhanced by additional audio and video components as shown in Figure 6.

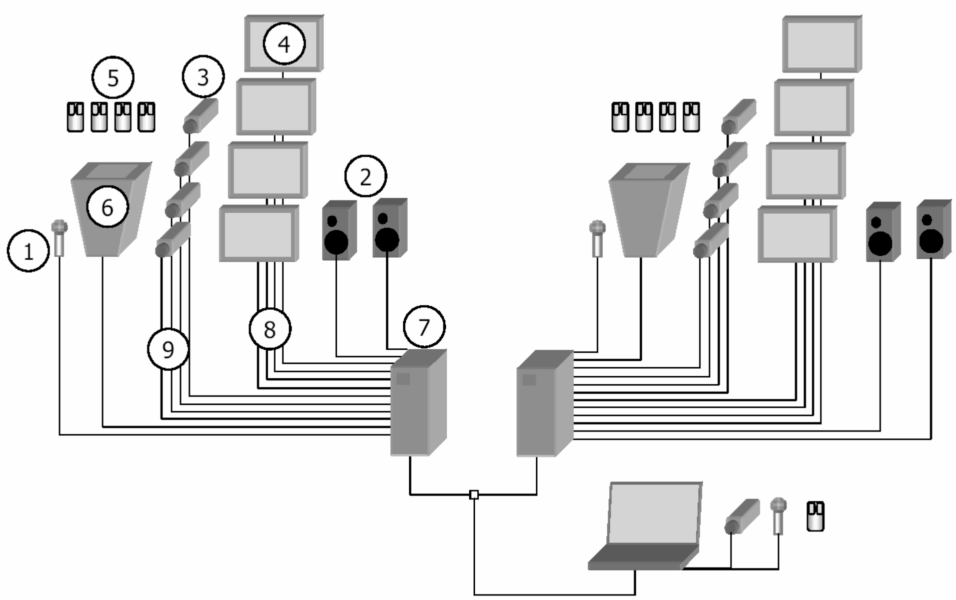


Figure 6 System set-up for collaborative work in distributed teams [9].

The complete set-up consists of six main components: audio in- and output devices (1 and 2), video in- and output devices (3 and 4), multi-user interaction tools (5), workplace (6) and computer (7). The computer contains multiple cards for video in- and output (8 and 9). The whole set-up is connected to other set-ups over a network, but it also can be used as a stand-alone solution to support local team sessions. Also the case is shown, that a single user is connected to the session using his laptop or his tablet PC. Figure 7 shows the modified system, which allows, that some users are connected to the session over a network.


Figure 7. Possible configuration of the set-up for the integration of net-based team members.

Since the loudspeakers are integrated into the monitors, a correct spatial correlation between the video and the audio signal is realized. The monitors are arranged around the table to reach a more intuitive discussion in the group. First tests showed that for an intuitive collaboration it is important to have a correct eye-contact with the remote collaboration partner, since it is one important carrier of the Meta information. It supports a coordinated discussion and also helps to understand the spoken word.

## 4. Conclusion

The increasing propagation of mechatronic products and the globalization of companies and the product development process result in the need of collaboration with internal and external partners. This requirement for collaboration can only partly be covered by the existing technological means. Therefore, a system was introduced in this paper, which allows a simultaneous work on a common interaction space between collocated team members. Within a next step the system was enhanced by integrating net-based team members into the creativity session. Beside the description of the realized hardware, also the software was introduced, which allows the transfer of audio and video signals as well as the simultaneous writing and sketching on a common workspace.

As a first proof of concept we realized a small application, 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 of other dedicated devices like eraser, marker, or reminders. It wasn’t possible yet to combine two identical workplaces, but team sessions using tablet PCs were performed, instead. This also allowed a collaboration over the network, although helpful functionalities were not available in this case.

## 5. Future Work

In a next step the interaction devices will be further improved in order to allow a more intuitive handling of the system. Here, additional interaction devices like an eraser will be realized. Also the possible additional buttons will be used and integrated, e. g. a 4-color-pen. Since microelectronic components will be used, typical sizes of the interaction devices can be realized. In addition, a second set-up will be realized (see Figure 6) in order to perform a complete net-based creativity session with all possible features.

Also further improvements of the software are planned in order to define and prepare a team session more quickly. Typical session scenarios can be predefined and just called up in order to also allow ad-hoc sessions.

By creating suitable scenarios, it is planned to also integrate the results in the collaboration and education between universities. As a first step we are planning a students’ exercise in order to continuously validate our results in real applications.

## 6. Acknowledgements

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