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TOWARDS TRUE COLLABORATION IN GLOBAL DESIGN TEAMS?

Peter Törlind, Andreas Larsson, Magnus Löfstrand, Lennart Karlsson

Abstract

Today's collaboration tools can support formal meetings to a certain extent, though there is still an immense potential for improvement when it comes to designing virtual and physical places where global design teams can collaborate in more 'natural' ways than existing distributed environments allow. One challenge for global product development is to support true collaboration within global design teams, where diversity and competences of the whole team can be utilized and where team members can *think together* rather then merely exchange information, opinions and divide work. This paper summarizes the results of several case studies and development projects performed within the Polhem Laboratory over the last four years and proposes challenges for future research. From our findings some of the most important challenges are how to support users with communication tools for more natural formal and informal communication (i.e. as a co-located team communicates), while automatically storing information and context from the distributed meetings.

Keywords: computer supported cooperative work, computer aided design, distributed product development, distributed engineering

1 Introduction

Demands on product development are ever increasing [1], and being able to develop radically shorter design cycles is of great interest: being able to build digital models, verify concept functionality and plausibility by relevant simulations, and finally, simulate production and sales of the product, all in a few days. To do this, the importance of design concepts to accurately predict outcomes increases to new levels.

Global collaboration in the design process is today a reality for many companies, often resulting from mergers between several companies. The use of distributed design teams is also common in Virtual Enterprises within complex systems engineering companies, such as those active in the aerospace sector. Virtual Enterprises consist of a temporary network of independent companies who share skills, costs and markets with neither central offices nor organization charts [2]. To cut costs and time, while meeting quality demands, these companies are forced to collaborate. Unfortunately, such global partnerships involve immense challenges regarding distributed work.

A new industrial demand has been recently identified - products capable of being sold as functions in addition to the parts of which they constitute (Hardware, Software and Services) – so called 'Functional Products'. Due to the number of diverse disciplines that are affected by or involved in developing a Functional Product (these disciplines include, but are not limited to design, management, production, marketing and legal), additional demands on communication, collaboration and trust arise. A greater number of disciplines that are increasingly distributed geographically will need to work together to create Functional

Products. By considering these changes in product development, an increasing importance will be afforded to improving the performance of distributed teams.

In many distributed projects the collaboration between various distributed groups are often restricted to coordinating separate sequential tasks. Future challenges for distributed teams are to reach *true collaboration* – to utilize the diversity and competences of the whole team, and simultaneously bridge communication gaps between both technology and humans.

This paper summarizes the results of several case studies and development projects performed within the Polhem Laboratory over the last four years, as well as comparing the projects and proposing challenges for future research.

2 Background

Multidisciplinary work and concurrent engineering have been established methods in industry for many years. One main principle of concurrent engineering is multidisciplinary, or cross-functional, teams that collaborate across traditional, functional areas of expertise. One main concept is for designers to use their different backgrounds and professions to influence the final design. These teams should work together towards a common set of consistent goals, supported by an integrated computer environment where the information is shared between teams, machines and processes [3].

Fundamentally, development activities should preferably be carried out in parallel rather than in sequence, and if such collaboration is to be successful, it is very important to "*improve communication between the many involved people including management, designers, product support, vendors and customers.*" [4]. Because of globalization, the multidisciplinary team may be located in several sites around the world; collaboration between these dispersed groups often presents considerable challenges.

However, in addition to accessing defined data subsets in a suitable form, communication also concerns human to human communication, where a good design relies heavily upon the ability of a cross-functional team to create a shared understanding of the task, the process and the respective roles of its members [5, 6].

2.1 Functional Products

Behind the shifting industrial focus from hardware to functional products lies the fact of new business drivers which have been described by Brännström [7]. Interest in functional products has been expressed in a range of Swedish companies [7, 8]. According to Brännström, a Functional Product (FP) "*combines the lifecycle processes of hardware, software and services.*".

This need might be met by a total offer, sometimes in the form of functional sales. The effect of expanding this product definition is that it will be increasingly difficult to develop products in-house mainly because the concept implies an increased and stronger collaboration between engineering departments and departments with whom they have had no normal communication with in previous non-FP projects.

Due to the number of diverse disciplines affected by or involved in developing a Functional Product, new demands on communication, collaboration and trust between multi-disciplinary teams arise [9, 10]. The effect of Functional Product Development on today's engineers is suggested to be an increased contact area between traditional engineering design teams and other departments, customers, subcontractors, etc. The composition of these design teams should be reorganized to support multi-function design covering a wider range of company functions.

2.2 Distributed Work: The Problems of Globalization

Even a small distance greatly reduces daily contact and informal communication between collocated team members [18]. Allen [11] states the *"50 ft rule of collaboration - teams are essentially 'distributed' if they are more than 50 feet apart"*, i.e. over this distance problems of being separated increase substantially. In this paper, the term distributed is used when teams are located in different geographic locations.

Many globalisation related problems introduced below are described in the literature, that occurs specifically for distributed teams:

- Team members working in a virtual, distributed environment have problems with carrying out information transfer and creating a common understanding [12, 13, 14].
- Other challenges for distributed teams include issues of proximity, awareness, communication latency [15, 16, 17].
- When product development is done in a global team participants are more likely to have different backgrounds and perspectives. The heterogeneity of culture, technical disciplines, language, etc., is commonly much more extensive in a distributed team than in a local team. These differences further complicate the collaboration [12, 18, 19], and if the teams are spread over different time zones, an additional problem arises since synchronous communication may be hindered due to limited overlap in work hours [12, 16, 29].

Collaboration problems often change during the design process. Kleinsmann and Valkenburg [20] categorized barriers in three different levels, and found that barriers at the *participant level* occur in the early design phases, barriers at the *project level* increase during the project and *organizational* barriers mostly occur at the start of the project.

Problems normally found within co-located teams, such as lack of information, problems with support tools, and conflicts between people, increase with distribution [21].

Distributed work also has several advantages. Larsson et. al. [16] has identified several opportunities with distributed teams compared to collocated teams, such as team diversity and market closeness.

Global design requires extensive communication between participants and several notations exist to categorize different levels of communication. MacGregor defines the difference between collaboration, cooperation and coordination [22] as:

- *Co-ordination is the organisation of resources or elements, usually within a complex body or activity, so as to enable effective collaborative work.*
- *Collaboration is the action of working with someone to produce or create something, usually where the parties involved have a common goal or interest.*

- *Co-operation, often used interchangeably with collaboration, is the process of working together to the same end. By definition, there is little to separate both terms other than collaboration represents the action and co-operation the process.*

The authors of this paper agree with Dillenbourg et. al. [23, p.189], who provide a functional difference between cooperation and collaboration: *"Cooperation and collaboration do not differ in terms of whether or not the task is distributed, but by virtue of the way in which it is divided; in cooperation the task is split (hierarchically) into independent subtasks; in collaboration cognitive processes may be (heterarchically) divided into intertwined layers. In cooperation, coordination is only required when assembling partial results, while collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem."*

The purpose of making this distinction is not to provide a rigorous definition of very closely related terms, it is to highlight that we see a potential for an even closer collaboration between remote partners.

2.3 Computer Tools for Design Collaboration

Computer Supported Cooperative Work is the scientific discipline that seeks to understand how people work together, how to design appropriate computer-based support and how these technologies affect group behavior [24, 25]. Bannon and Schmidt [24] describe CSCW as *"an endeavour to understand the nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies."*

Today, a multitude of Internet-based collaboration tools exists for both asynchronous and synchronous collaborative work. However, most commercially available software tools focus on the later stages of the design process [26], where information is typically more structured, and information exchange processes can be more easily formalized. The early, creative, conceptual design phases are typically less structured, requiring a lot of ad hoc interactions and highly interactive meetings relying on swift and unrestricted information exchange. These types of interpersonal interactions are typically more cumbersome to support using computer-based support tools.

The EC funded *Future Workspaces* [27] presents a roadmap for future collaborative workspaces, where one of the research targets is: *"Establish network independent and scalable services to access audio-visual materials, 3D and mixed reality objects, distributed speech recognition over heterogeneous infrastructure with variable bandwidth and quality of service availability with a high trust level."*

Many research tools and commercial products claim to bridge distance and solve communication problems, though there is still a huge difference between distributed work and co-located collaboration. This statement from Olson & Olson [12] in 2000 is still valid: *"although we will be able to bridge some of the distance and make communication richer for remote work than it is today, distance still matters"*.

3 Methods

The input for the findings presented in this paper is based on a literature study and results from several case studies done by the Distributed Collaborative Engineering research group at the Polhem Laboratory, Luleå University of Technology over the last few years. These projects involved both distributed and co-located design teams, and included student projects in collaboration with companies as well as case studies in automotive companies, aerospace companies and component suppliers. Some of the major projects are listed below:

1. A 6-month case study where engineers from two Swedish industrial companies (Hägglunds Drives AB and the consultancy firm Conex AB) collaborated in a distributed setting [28].
2. A one-year student project where engineering students from LTU collaborated with students from Stanford University to develop a new type of pedal interface for Volvo Car Corporation [16, 29, 30, 31].
3. Studies at a component maker for trucks [32]
4. Two studies at BAE Land Systems Hägglunds; one focused on distributed and co-located collaboration, the other on interaction with physical objects in distributed meetings [33, 34, 35].
5. Studies at two different engineering departments of Volvo Car Corporation.
6. A one-year technology study where a prototype framework for winter car testing was designed by combining telemetric technologies, distributed Virtual Reality and broadband conferencing [36].

Other distributed projects observed include collaborative student projects between Luleå University of Technology, Chalmers University of Technology, the Royal Institute of Technology in Sweden and Stanford University, CA, USA. The research team has also been involved in the DITRA project, a development project created to utilize distributed collaboration technologies in industries in northern Sweden with the objective to increase their competitiveness [37].

4 Main Findings

In this section, we present some of the main findings from the above mentioned projects. The findings indicate that numerous challenges need to be addressed if ‘true’ collaboration in global teams is to be achieved. A summary of the projects can be found in Table 1.

4.1 Hägglunds Drives Study

The study at Hägglunds Drives indicated that computer tools simplified communication and enabled meetings several times a week instead of once every two weeks. The users experienced a clearer focus in the project when using distributed engineering technologies, and commented that the usage of competence and knowledge at both places improved because the communication tools simplified communication. Also, informal communication within the project was improved. For the consultant the project changed from an ordinary consulting assignment (with design goals, weekly progress reports and a final delivery of a design document) to a more flexible project where closer collaboration between the companies existed, where ideas were discussed daily, problems were rapidly solved and new directions for future work came up.

Table 1. Summary of the projects.

Summary of the projects followed

Study	Focus	Type of study	Size of group in collaboration	Main findings	New tools implemented	Challenges
Hägglunds	Introduction of distributed collaborative tools for synchronous communication	Ethnographic study, Interviews, empirical data collection	3+2	Limitations of whiteboard tools Steep learning curve for collaboration tools	Broadband conferencing tools	Steap lerning curve of tools, poorly designed tools
DTI	Informal communication.	Ethnographic study, empirical data collection	4+4 students 1+2 teaching ass (management)	Limited informal communication between remote team members Low awareness of what was going on at the remote site	Contact Portal [27]	Informal communication [27] Side conversation [28] Importance of shared objects in design [29]
Ferruform	Which tools are needed for collaboration	Ethnographic study, particaptory design, interviews	Varying 5-10 persons in several groups	Importance of physical prototypes, importance of low cost collaboration tools		How to interact with physical objects in distributed design.
Land Systems Hägglunds 1	Barriers for collaboration	Ethnographic study, interviews	Varying	Documentation burden Document flow		Automatic storage of information from meetings.
Volvo Cars Corporation	Social connectedness. Informal communication.	Ethnographic study	Varying	Social capital is important. Knowing-who-knows and knowing-who-to-trust is essential to successful decision-making.		Finding the person 'behind' documents. Locating expertise. Knowing what information and people to trust. Storage of design rational
Distributed Winter testing	Supporting remote monitoring of cars on proving ground	Evaluation of prototype systems	2 groups	Collaboration tools can streamline processes	Shared VR-application for remote monitoring of vheicles	Security issues,
Land Systems Hägglunds 2	Physical artefacts in distributed design	DRM research method	1-7 local 1-12 remote	Importance of physical prototypes	Mobile communication tool [32]	Interaction with remote physical objects
DITRA	Synchronous communication Distance education	Participatory design	Varying, 2-11 distributed groups with total of 2-60 participants	Difficult to perform large meetings, how shall many groups be represented	Tools for synchronous communication and physical environments for collaboration	Ease of use of communication systems, Large group meetings Floor control in meetings Storage of information from meetings

Some of the collaboration tools tested in this study, e.g. shared whiteboards, were found too cumbersome to work with. Instead, normal whiteboards were used and the camera was moved to allow for an unimpeded view. As well, the learning process for some of the collaborative tools was too long, and the setup of a conference was sometimes experienced as too cumbersome due to the technology in itself (such as audio, audio cancellation, cameras, etc.) requiring some time to learn how to use it fully. Coupled with misunderstandings of the interface, it was concluded that much work is yet to be done when it comes to user friendliness and stability of service.

In addition, this project revealed several technical and organisational issues such as network demands and meeting preparedness.

4.2 The DTI-project

The main findings indicate that the flow of informal information between remote team members was very low compared to that between local team members; team members also had a low awareness of what was going on at the remote site. To address these issues, some tools such as the Contact Portal [29] were developed, acting as a natural starting point for initiating and maintaining contact with remote team members.

The high-quality videoconferencing capability enhanced the ability to understand body language and other non-verbal information, making physical proximity less of a concern compared to telephone conferencing and low-quality videoconferencing.

However, several issues observed during co-located meetings were not observed in distributed meetings; i.e. *interaction with physical objects* and *side-conversation*.

Interaction with physical objects: team members could easily share the geometry of a concept (using shared applications and CAD-models), and discuss the physical object via videoconferencing. As well, they could successfully negotiate a shared understanding of how it ‘feels’ to drive with Virtual Pedals, or to shape consensus about concepts of ‘comfort’ and ‘ease of use’, when only one of the sites has access to a physical prototype.

Side-conversation: in the study, it was also noticed that one-on-one conversations held simultaneously with a main discussion were common in collocated teamwork, and they served as a natural part of creative teamwork [30]. Current systems for distributed collaboration cannot provide sufficient support to these subtle interactions, which has important implications for supporting and improving the performance of global teams by suggesting that the one-to-many channel of today’s videoconferencing is severely limiting, despite the current advantages of high-quality audio and video.

4.3 The Ferruform study

In this project slightly over 6-months, a design group at Ferruform was followed, and both co-located and distributed meetings were studied.

Interesting results were the comparison between the same type of meeting in a distributed and a co-located setting. In a distributed meeting (via telephone conference), much less interaction occurred between team members than in a co-located meeting. Obviously, the medium (telephone) prevents the user to explain difficult issues satisfactorily.

Another problem in distributed meetings was the interaction with physical objects. In local meetings the team often went out to the work shop to inspect a stamping tool or analyze problem areas in the production process. These issues could somewhat be solved in a distributed meeting by using a camera to document a specific issue and send the photo to all participants before the meeting, though the comprehension of the problem was much better when the team did a physical visit in the workshop.

4.4 Land Systems Hägglunds - Study 1

In this project a design group was followed over a period of six-months, with four weeks of site studies evenly distributed over the whole period. The project included a customer outside Sweden, several Swedish consultant companies and several divisions within Land System Hägglunds.

Among the findings from the project were the problem of *Document flow and Documentation burden,* i.e. optimizing the amount of documents sent to increase awareness and accessibility and keep all participants satisfied, without flooding them with unnecessary information. Users within the company could share documents readily; e-mail was used to share documents externally. In this process the final document was hard to find, and the review process was almost impossible to follow.

Another finding was the *Dependency on personnel:* This concerns the project's vulnerability, since in some cases key personnel such as the manager would have been difficult to replace due to his extensive knowledge of all aspects of the projects.

4.5 Land Systems Hägglunds - Study 2

This study focused on the importance of physical prototypes in distributed design, inspired by the findings from the DTI and Ferruform studies. In an attempt to realize this, a descriptive study observed co-located design reviews where a physical prototype was used. At Land Systems Hägglunds, a physical mock-ups was used to verify the design, to learn and to facilitate collaboration. The physical mock-up was often used to resolve design issues, to discuss system integration between different subsystems and as a physical embodiment of how the project was proceeding.

The study of co-located design reviews provided valuable input to the design of a wearable conferencing unit that was later used for distributed design reviews. The new system, tested and evaluated on distributed design reviews, allows remote users a first person view of the mock-up. With the new tools the remote engineers can share their *"virtual' CAD-data simultaneously as the mechanic situated at the prototype shares his "physical' data with the engineer*. The new tool also provided support in a co-located setting; users can look behind panels and view items normally hidden from the user's sight. This enables all members of the design team to have access to information regarding the project within minutes without relocating.

The project also highlighted the importance of physical prototypes. The new tool clearly enhanced remote work, though several issues still remained, e.g. problem to test and evaluate ergonomics and tactile properties such as weight of objects, friction in mechanical links, etc., from a remote location.

4.6 Volvo Car Corporation

Ethnographic work at two different engineering departments at Volvo Car Corporation revealed, among other things, current collaboration in co-located teams to be heavily influenced by the social interaction between team members. Since formal meetings mainly included project leaders of various kinds, it quickly became evident that the sharing of knowledge and expertise to other team members fundamentally happened through informal channels.

The work highlighted that "knowing who knows' is crucial for engineers regardless of location, since many problems and activities require contributions from other people with previous experience. As well, "knowing who to trust' is of great importance when trying to solve ambiguous and unclear design problems, since engineers are forced to trust the opinions of colleagues rather than blindly trusting facts or documents. The findings from the study not only point to the potential for companies engaging in global collaboration to leverage from a collective social capital, but also to the important challenge to improve how social capital is built and maintained in global collaboration.

In another study focused on design reviews at Volvo Cars Corporation, the storage of decisions in a distributed meeting used a primitive notation, *"it's not sophisticated, but it's easy to use"*. In the meeting, documentation from the final design solution was saved, though the design rational behind the decisions was difficult to find.

4.7 Distributed Winter Testing

In 2004, a framework for distributed winter testing was implemented, tested and evaluated under realistic conditions in cooperation with a winter test company in northern Sweden and a car manufacturer in southern Sweden. By introducing a framework for distributed winter testing (based on distributed engineering tools combined with telematics), temperature data from a test vehicle could be visualised at another location 1,500 km away. Despite the distance, the car manufacturer could follow the tests in real-time, communicate interactively with high quality and collaboratively interact with test engineers situated at the test facility. The presented system enables a new way of working with winter testing of vehicles, where companies can simplify the testing procedures and get a quick response and understanding of the process. It was concluded by the test car manufacturers that this type of system could save time and travel and will be essential in the future.

4.8 DITRA

The EC funded DITRA project introduces methods and tools for distributed engineering in industry. The DITRA framework consists of eleven studios for distributed collaboration, located in northern Sweden. All studios are connected via broadband network. Different types of communicating are done between them; education, distributed meetings, distributed collaboration projects, etc. Researchers from Luleå University of Technology have been involved, primarily as users and as technical support for other users. The DITRA project has contributed valuable experience in creating the required infrastructure, as well as testing communication technology on a daily use.

Findings from the projects include the problem of having large distributed meetings; normally, all eleven studios were connected simultaneously for project meetings. These meetings are much more formal and the requirements for floor control and a detailed meeting agenda is much higher than meetings with two or three sites.

The DITRA project has also focused of the technical problems of collaboration software today, e.g. even experienced users may have problems connecting to other users, the collaborative environment is dependent on infrastructure, computers and hardware that influence the quality of the communication, and if one part fails there is often no redundancy and the meeting must be postponed.

5 Summary of findings

From the different studies described in section 4, some general conclusions are presented:

Complexity of tools; a general problem found in almost all studies are the different tools needed for global collaboration, all with separate advantages, user interfaces and limitations. The success of using collaborative tools depends greatly if the users are familiar with the technology and if the equipment (e.g. lightning, microphones and cameras) is adjusted properly; if not, problems can be difficult to locate and eliminate. Even broadband conferencing systems capable of high resolution conferencing with CD-quality audio can be ruined by using the wrong types of microphones or by acoustic feedback.

Natural communication; informal communication, brainstorming and prototyping are less common between distributed team members than co-located teams. These types of meetings seems much harder to support than meetings later in the design process where computer models, requirements, etc., exist and the meetings are well documented. In the DTI study, a design team consisting of members located in the USA and Sweden sometimes brainstormed together for several hours. But when following the same type of meetings of a co-located team, the meetings were much less formal and side conversations between team members were more common. To reach common ground users involved the telling of stories and an extensive use of indexical representations. When verbal language was not enough, gestures, chairs, sketches, prototypes and all possible types of objects to visualize and describe what they wanted to 'say' were used. The overall structure of the meeting was more fluid, though there was no interruptions due to technical problems, etc.

Physical artefacts; in many projects the use of physical prototypes or other physical artefacts were an integral part of the design process. In design discussions within the DTI-project, members of the design team made use of just about anything that could help them communicate their ideas. Prototypes were often used as a proof of concept and to facilitate communication, and visits to the workshops were used to clarify design issues.

Lack of collaboration; In many of the studied distributed projects, the project teams have been rather small and the total group of collaborators is often less than 10 participants; therefore, the influence of managerial and organizational problems has not been studied. Building and maintaining trust between members is also easier in smaller groups. When following large distributed projects in industry, this type of close collaboration is rarely the case. Many distributed collaboration projects are reminiscent of parallel product developments that are divided into different tasks. In complex projects, these tasks are designated to specialists groups often located in different companies. The cooperation between the groups is commonly restricted to only a managerial level. Design influence between groups is rather small, often restricted to the interfaces between the groups' respective responsibilities (i.e. a specific hardware component), where the teams have to agree on the interface design. The information flow between the design teams will thus follow the structure of the hierarchical organization where much information is filtered through the project leader, who may or may not be involved in the detailed design issues, thereby the sharing of knowledge and expertise between other team members are based on informal communication.

Documentation has been found to be a problem in most of the studies, systems for sharing documents are used, but finding documents is still difficult. At the same time there is an information overload when users are flooded with e-mails and attached documents that may be unimportant to them. Synchronous meetings and design reviews are often poorly documented; usually a short note with the issues discussed and decisions taken are documented from a meeting. The design rationale is frequently not documented at all. Creating documentation within a design process is often a joint work claiming to be collaborative, in reality usually consists of a sequential view and mark-up review process with very little personal collaboration [38].

6 Challenges for future research

One challenge is the development of tools and methods that support *true collaboration* within global design teams, where diversity and competences of the whole team can be utilized and where team members can *think together* rather then merely exchange information, opinions and divide work. Team members must be supported by new innovative collaborative tools that allow users to communicate with both formal and informal communication in a more natural way (i.e. as a co-located team communicates).

Many of today's tools have the focus from the technology standpoint, and force the user to work in a specific way. The technology focus – 'what can' approach takes the basis in integration and communication technologies, whereas the user focus – 'what needs' approach requires a deeper understanding and analysis of the information and communication processes. A typical example is video conferencing that supports communication between team members, but forces the user to work in a specific way (e.g. side conversation is not possible, eye contact is difficult to archive, and users should sit in one place and not walk around in the room). Challenges for the future work must explore what needs to be communicated rather than what can be communicated.

6.1 Automatic storage of information

By creating distributed environments that allow for transparent storage of information and events in the distributed engineering environment, the documentation burden is lowered. The information could, for instance, be used to create a shared design document after a synchronous collaboration session has taken place. By using a common framework for collaborative environments, where all events made in the distributed environment (e.g. all visualizations of models, viewed movies, viewed documents, decisions, audio and video from the conferencing system) can be stored, we can extend the reprocessability.

These types of tools can also be used for dynamic documentation, turning the documentation task into a parallel activity within the process to increase agreement and thereby decrease revision and time-to-acceptance.

Challenges for storing and reusing information and knowledge, to mention a few:

- *Reuse*: support the reuse of documents and other information.
- *Design rationale:* why a decision was made, understanding why people rejected certain solutions, why it did work, why it did not work, etc.
- *Reasons for design*: increase awareness of what you have learned, not only what you have produced!
- *Reprocessability:* i.e. how much a message can be re-examined or processed again within the context of the communication event. This can also be used in a learning process, and to quickly bring new team members up to "speed'.

6.2 Social connectedness and informal communication

Findings from the followed project revealed that the collaboration tools of today - broadband conferencing, shared applications and whiteboards - can support formal meetings to a certain extent, though supporting informal meetings and distributed social activities is still a very challenging issue. One key to success might very well be the ability to adequately support social connectedness between remote team members and thereby facilitate the informal communication processes that often arise spontaneously in between the formal meetings.

Challenges include:

- Creating a social connectedness and awareness of other users and processes.
- Support of informal communication in between formal meetings.
- Support for creating the social capital (knowing who knows and knowing who to trust) and finding the person 'behind' the e-mails and documents.

7 Conclusions

Although advances in broadband videoconferencing systems show promising results in sending and receiving 'hi-fidelity' audio and video across continents, there is still an immense potential for improvement when it comes to designing virtual and physical places where global design teams can collaborate in more 'natural' ways than existing distributed environments allow. By following several distributed projects, it has been shown that some types of meetings, such as formal meetings, design reviews with digital information, etc., can successfully be supported to a certain extent using advanced computer based collaboration tools and broadband connections.

However, there are still many challenges for distributed collaboration; from our findings some of the most important challenges are how to support informal communication within distributed teams and automatic storage and retrieval of information in distributed meetings.

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Peter Törlind, Polhem Laboratory, Division of Computer Aided Design, Luleå University of Technology,
SE-971 87 Luleå, Sweden, Tel: +46 920 492412, Fax: +46 920 99692, E-mail: Peter.Torlind@ltu.se,
URL: *http://www.cad.ltu.se/*