Tele-Board: Enabling Efficient Collaboration In Digital Design Spaces

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***Abstract*—Remote collaboration among geographically dispersed team members has become standard practice for many companies and research teams. A number of computer supported collaborative work systems exist, but there still lacks acceptable support for teams working in creative settings, where traditionally numerous physical and analog tools are used. We have created an environment for teams applying creative methods that allows them to work together efficiently across distances, without having to change their working modes. We present the Tele-Board system, which combines video conferencing with a synchronous transparent whiteboard overlay. This setup enables regionally separated team members to simultaneously manipulate artifacts while seeing each other's gestures and facial expressions. Our system's flexible architecture maximizes hardware independence by supporting a diverse selection of input devices.**

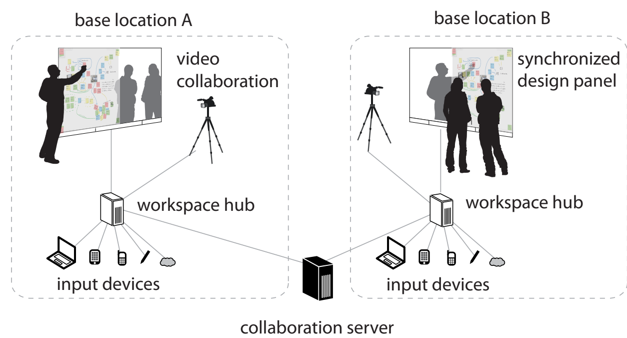

Fig. 1. Setup of the Tele-Board prototype

I. Introduction

Collaborative creative work is done best in co-located settings [12]. People directly communicate with each other, see each other's gestures and facial expressions, and manipulate all involved artifacts. Sticky notes, whiteboards, walls, pens, all imaginable prototyping material and methods like role-play or storytelling may all be used when creative methods such as design thinking are applied [2]. Furthermore, bringing together the insights of research and different perspectives of a diverse team is a key factor for successfully fueling innovation [30]. In order to incorporate different cultural aspects as well, international teams are often favorable. But how can teams reasonably use the above-mentioned analog tools if members are geographically dispersed, and time zones separate them by several hours? Can suitable digital equipment replace these tools to support teams in their usual way of working, regardless of members' locations?

A number of tools supporting remote collaboration already exists. In the last years, commercial products for remote collaboration improved tremendously to enable easy video conferencing with various levels of quality and costs. But satisfactory support for distributed creative working does not exist yet. Most tools only support standard desktop tasks and are cumbersome to use [11].

Scientific research projects that study how people communicate remotely and share working materials across distances exist for almost twenty years. But remote collaboration encompasses a variety of different aspects, and these systems have focused on specific use cases. Some concentrate on the role of audio and video (with no whiteboard support) [8], [14], [18], [29]. Others do not involve video equipment at all and focus on sharing digital desktop artifacts [7]. Some projects do focus on working at whiteboards (e.g. [6], [12], [15], [26], [27], [28]), but often the input devices differ significantly from traditional whiteboard tools. Thus, the systems are hard to use, which results in problems with their adoption [13]. Dedicated support for design work is not yet available.

Based on the research results of the above mentioned projects and our observations of design teams at work, we developed a groupware system for co-located and remote setups, which resembles the usage of traditional whiteboards. The Tele-Board system is an electronic whiteboard software suite which allows users to write digital sticky notes on Tablet PCs, smartphones or directly on a whiteboard. You can move the created sticky notes, cluster them and write or draw on the whiteboard. This digital implementation also includes additional features - previously unrealizable by physical tools - such as resizing sticky notes or changing their color. All of the mentioned actions are synchronized automatically and propagated to every connected whiteboard client. To facilitate a real interactive session, we include a video conference feature for distributed team members. The translucent whiteboard can be displayed as an overlay on top of the full screen video of the other team members (see Figure 1). This setup lets everyone see what the other participants are doing and where they are pointing at. Additionally you can see their gestures and facial expressions.

It is important to us that the system is easy to use and has a shallow learning curve. Therefore we used "simple and understandable metaphors" [25]: all interactions are designed to resemble the usage of traditional whiteboards and sticky notes as closely as possible. Furthermore, all team members can choose the input device they prefer for the creation of sticky notes (e.g. a Tablet PC, smartphone or chat client) . With our flexible architecture, it is easy to add many other types of devices to the system, regardless of the manufacturer. Tele-Board can be used for both co-located and remote setups. The whiteboard and sticky note application runs on any computer, i.e. you can start them on large interactive displays, Tablet PC's or normal desktop screens. Thus, the whiteboard content is "constantly visually available" [25] and can be edited anytime and anywhere. As all whiteboard artifacts are synchronized between whiteboards, every user can always see the team members' actions and manipulate all objects, as if they were using non-digital whiteboards. Seeing physical activity can be supported by a full screen video behind the translucent whiteboard surface. The team can choose between a full screen or split screen whiteboard layout depending on their preferences (see IV-C). With this setup it is possible to see gestures as in Tang and Minnemann's *VideoWhiteboard* [27] and the remote persons' faces as in Buxton's *Sitting across the desk* example [3]. Hence, Tele-Board offers the different types of spaces suggested by Buxton [4]: A *person space* of the remote partner's image, a *task space* of involved artifacts (= whiteboard) and a *reference space* for pointing and gesturing (see Figure 1 and 6).

In this paper we further elaborate on what we have learned from existing research projects and describe working modes that we defined from observations and interviews. Next we present our system's architecture, components, and functionalities. Our plans for further developments and testings are described in the last section of the paper.

II. Related Work

In this section we provide a brief overview of existing full-fledged tools that are designed to support collaboration between dispersed team members in the creative processes we evaluated (cf. III). We show relevant commercial tools as well as interesting scientific ideas and prototypes.

A. Commercial Products

A variety of tools that are commercially available, offer possibilities for remote collaboration. However, most products focus either on video conferencing capabilities or on sharing artifacts. A commonly used tool that offers both functions is Adobe Connect[1], which is mainly a web-based conferencing system and so-called learning environment. It features the most common tasks in a meeting setup including audio and video conferencing, screen sharing and a simple whiteboard solution. But the integration between these components is insufficient. For example, pointing at certain parts of a sketch on a whiteboard is hard to achieve in a video conference. Interviews with employees of large software companies using the software intensively showed that most of the functionality (e.g. the whiteboard component) is hardly used.

Telepresence systems such as those provided by Cisco or Polycom[2] are the most elaborated high-end video conferencing systems on the market. High definition video and audio as well as special security features make it only affordable and best suitable for big companies. Telepresence systems are basically an arrangement of hardware components. The most elaborated setup makes it possible to build up a virtual meeting room, so everyone in the meeting has the illusion of sitting together at the same table. The critical drawback for creative work is the missing support of synchronous whiteboard interaction.

There are several commercial and non-commercial web applications which focus on enabling the user to sketch ideas on whiteboards[3] or sticky notes[4]. All of them provide simple means to draw sketches or create sticky notes and share them with colleagues. As with Adobe Connect the integration of audio or video conferencing is insufficient if it exists at all.

All of the above mentioned solutions do not support the users in actual collaboration with each other. People cannot properly sketch their ideas and discuss them with remote partners. Often, when switching from a co-located to a distributed setting and expecting to rely on these tools, a large emotional disconnect is built up between the communicating partners.

B. Research Projects

The first tools to support creative collaboration of spatially separated teams were *VideoDraw* [28], *VideoWhiteboard* [27] and *Clearboard* [15], each developed in the early nineties. VideoDraw and Clearboard combine synchronous drawing and the ability to observe remote partners at the same time. A desktop-like setup combined with cameras is used to reproduce drawings from one side on the other. VideoWhiteboard fits the requirements of our working modes more closely, as it transfers whiteboard content with the help of rear projection to the whiteboard of a remote person. Additionally, a shadow image of the remote person's upper body is transferred to see gestures of the partner. Seeing only the shadow and not a real video of the other person is one limitation which Tang and Minneman point out themselves [27]. Even more important is the missing functionality of manipulating the other person's drawings and other artifacts they created. This drawback also arises with the Clearboard and *Facetop* [24] system, although it is possible to see a real image of the other person rather than only a shadow.

Everitt et al. [6] also used shadows to mimic the remote person's presence. They augmented *The Designer's Outpost* from 2001 [16], a collaborative tool for website design. Users apply digital sticky notes to sketch the intended structure of the planned website. Much research effort has been spent on computer vision techniques to digitalize paper sticky notes and keep them synchronous with their analog counterparts. In addition to vision-tracked shadows, Everitt et al. also used transient ink to convey deictic gestures. For example, participants drew arrows to show their remote partners where

[1] http://www.adobe.com/products/acrobatconnectpro

[2] http://cisco.com/web/go/telepresence/, http://polycom.com/telepresence

[3] e.g. http://dabbleboard.com, http://skrbl.com, http://imaginationcubed.com

[4] e.g. http://listhings.com

they would move a sticky note. The transient ink arrow disappeared after several seconds. The Designers' Outpost hereby presented a very promising approach to working with sticky notes on a digital whiteboard. Representing gestures with shadows and ink improves remote collaboration. But as the authors already mention, the shadows cannot convey human characteristics. Facial expressions are not visible at all and the transient ink feature is often ignored. Additionally, the system would need audio support to be considered a real remote setup.

Another project with a similar approach is *Video Arms* [26] from 2006, which uses digital embodiments to enable pointing in a remote setting. A computer vision approach is used to capture the arms of the people, cut them out of the video image, and then reinsert a translucent version on the remote screen as well as on the local device. The main drawback of this solution is that the focus on body gestures is limited only to the arms. Eye contact and full body gestures are not transferred to the remote location.

Hilliges et al. [12] present a brainstorming tool which supports writing digital sticky notes on an interactive, touch sensitive horizontal surface. At the same time the sticky notes appear on a vertical display to allow working at a whiteboard. It would be interesting to investigate how this "holistic digital environment" approach could be transferred to a distributed location setup, as it currently only supports co-located settings. There are various other digital whiteboard systems which were developed in the past twenty years (e.g. *Flatland* [21] or *Tivoli* [23]), but most of them are also only developed for co-located use and do not focus on remote setups and therefore do not involve video functionalities.

All aforementioned systems offer interesting functions for remote collaboration, but each of them also has major drawbacks, especially for supporting creative work (see also Figure 3 for a comparison of systems). Our goal is to overcome these drawbacks with Tele-Board. In the following section we describe requirements for a system that supports design thinking working modes.

III. Working Modes

In order to anticipate user needs and requirements for a tool aimed at supporting design teams, we needed to understand the way they work and interact. We wanted to develop a software suite that would truly support and optimize collaborative creative work without getting in the way of the team members involved in the process. As Greenberg states, "groupware design must begin with observations of actual working practices"[10], we started by interviewing and observing teams working with whiteboards. We wanted to find out how people work with each other and how they interact with all involved artifacts. In contrast to Tang et al. who observed whiteboard use in different situations [25], we were only interested in collaborative synchronous whiteboard tasks, as our first goal was to support these tasks remotely.

Through our observations we found out that users have different needs in different situations. To classify these needs we identified seven main working modes (see Figure 2). These modes can be expanded by other modes as working techniques vary depending on organizations and groups.

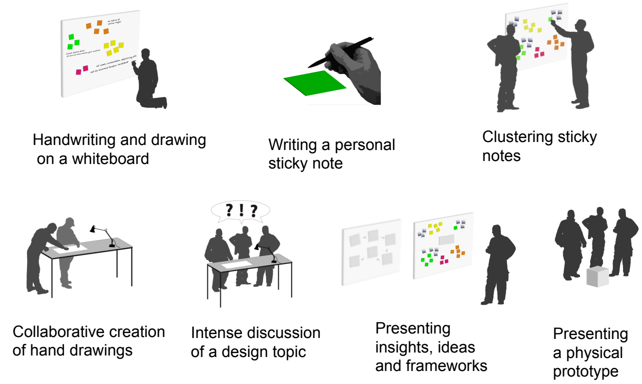

Fig. 2. Working modes at design thinking projects

A. *Handwriting and drawing on a whiteboard*

This working mode happens often and for various reasons during a design session. People note facts or ideas, visualize these ideas through rough sketches, or draw a diagram to explain relations. Multiple colors and an eraser are typically used, as well as printouts of pictures and other information. It is important that the whiteboard stands vertically to be seen easily by all team members. Each team member must have direct access to the whiteboard. Gestures are frequently used to support the communication of ideas to other team members.

B. *Writing a personal sticky note*

Sticky notes are used to note down facts or ideas, sometimes including small drawings. The creation of sticky notes is often done individually and simultaneously by team members. Sticky notes may be added to the whiteboard either continuously or during a quick personal presentation of everyone's ideas. Colored sticky notes are used to differentiate between their content's source.

C. *Clustering sticky notes*

Typically, one or two team members stand in front of a whiteboard to cluster the team's sticky notes. A cluster is often defined by circling a group of sticky notes with a whiteboard marker and applying a label. Other team members may instruct them from somewhere in the room. The team tries to group related research information or ideas generated during a brainstorming session. It is important that all team members can see all information. Moving sticky notes around must be easy and all team members should be able to see each other's pointing gestures because users shall find main insights and frameworks as a team.

D. *Collaborative creation of hand drawings*

Usually one person creates a drawing or sketch in more detail and the other team members give feedback. It is important that all people involved can see the drawing and may contribute to it.

	Support for design work						Support for remote collaboration		
	User Interaction			Artifact integration					
	Handwriting and drawing	Personal content creation	Several local participants	Editing of local and remote artifacts	External media	Expression of artifact interrelation	Full-body gestures	Facial expressions	Connection between video and workspace
VideoWhiteboard [27]	✓						✓		✓
Clearboard [15]	✓						✓	✓	✓
VideoArms [26]	✓		✓	✓	✓				✓
Designer's Outpost [6]	✓	✓	✓		✓	✓			✓
Facetop [24]	✓		✓		✓		✓	✓	✓
Agora [18]	✓		✓				✓	✓	(✓)
Tivoli [23]	✓		✓						
Flatland [21]	✓	✓	✓		✓	✓			
Hilliges et al. [12]	✓	✓	✓		✓	✓			
Adobe Connect	✓			✓	✓			✓	
Tele-Presence			✓		✓		✓	✓	
Skype					✓		✓	✓	
dabbleboard.com	✓			✓	✓	✓		✓	
listhings.com		✓		✓					
Tele-Board	✓	✓	✓	✓	✓	✓	✓	✓	✓

Fig. 3. Comparison of existing systems and their relevance for our working mode requirements

E. *Intense discussion of a design topic*

The team meets to discuss a topic related to design artifacts, which are most often laid out on a table. Eye contact and visibility of gestures and facial expressions, as well as related artifacts such as pictures or other documents, are crucial.

F. *Presenting insights, ideas and frameworks*

This working mode often involves a bigger audience. The team presents the insights they have gathered and the frameworks they have created. It is important to collect as much feedback as possible from the audience.

G. *Presenting a prototype*

In this working mode, the team most often presents a physical object from all sides to the audience, in order to obtain as much feedback as possible. Alternatively, the team might act out a concept in form of a skit.

From these working modes we derived requirements, which are important for a design collaboration system. In close relation to the first working mode, the tool shall support direct input for handwriting or drawing. As teams want to do this together it must be possible to edit local *and* remote whiteboard artifacts. Additionally, the system shall support the creation of personal content and several people may do it simultaneously – at the same and at a remote location. These two requirements address the second working mode as writing personal notes is crucial during various phases of the design process. For the generation of ideas and frameworks it is important not only to rely on whiteboard skribbles, but to include other media as sticky notes or pictures as well. To support the clustering or grouping of ideas, expressing artifact interrelations would be a valuable feature. In addition to all these requirements for design work, the system must support synchronous remote collaboration to enable the last five working modes. It is essential to hear team members voices and to see their full-body gestures and facial expressions. For a successful communication and discussion it is very important that the workspace is linked to the video to enable pointing on whiteboard objects and thus conveying what you are talking about.

How different systems satisfy these needs is presented in Figure 3. In the next section we describe how Tele-Board addresses the requirements.

IV. The Tele-Board System

Our system aims at providing designers and researchers with a software that supports the working modes we identified using different digital input devices. It shall enable working over distance as well as at one location, while allowing pausing and resuming work at a different time or place. Hence the Tele-Board system needs to be able to transfer whiteboard content like sticky notes and support handwriting on electronic whiteboards. This transfer also includes natural user interaction with the simulated objects, i.e., the ability to add, move or remove elements to and from the electronic whiteboard using touch input or digital pens.

To support geographically dispersed teams, pairs of electronic whiteboards need to be synchronized over the Internet, i.e. user interaction on one electronic whiteboard should both influence the local and the remote whiteboard. To overcome physical limitations of today's electronic whiteboards on the one hand, and to support the working modes identified, Tele-Board also needs to support additional input devices besides electronic whiteboards. Hand-written notes play an important role in many design projects. In a digital setup, this can be simulated by using pen-enabled or touch-enabled laptop computers and smartphones. These devices can be used to write sticky notes in a private environment. Users must be able to transmit sticky notes from their private space using these devices together with an electronic whiteboard they are spatially associated with. In the following, the general architecture of the Tele-Board system is presented. We will show how the interplay of the system's components helps to meet all of the above mentioned requirements and how the integration of video conferencing works best.

A. Software Components

All activities in the Tele-Board software are centered around *projects*. A project can comprise all phases of a design activity and typically lasts for several months. During a traditional design thinking project, a fixed set of analog whiteboards will be filled with sticky notes and handwriting over the course of several hours or days, and later be photo-documented or cleaned to be used for new content. These ready-to-use surfaces of physical whiteboards are called *panels* in the Tele-Board data model. Panels do not have to be cleaned after being used, they are archived and can be restored. An arbitrary number of empty panels can be requested. The panels themselves can be filled with various *whiteboard elements*, such as sticky notes or handwriting.

In an ideal setup, panels are viewed and modified with the help of interactive whiteboard hardware, which can be connected to any computer. Decoupling whiteboard hardware and the whiteboards content adds flexibility as fewer – potentially only one – electronic whiteboards are needed to replace a traditional setup with analog whiteboards. To achieve this flexibility and independence from hardware devices, we designed the Tele-Board system to consist of four software components: a *web application*, a *whiteboard client*, a *sticky note pad*, and a *server component* (see Figure 4).

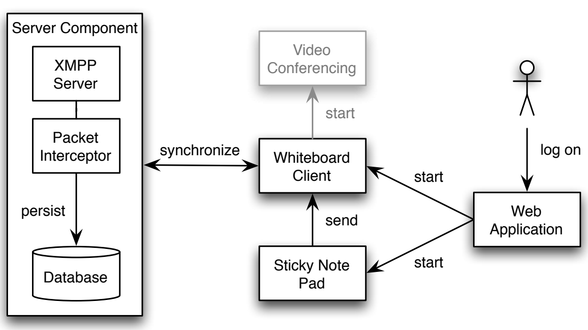

Fig. 4. Conceptual component model

1) Web Application: The web application serves as an entry point into the Tele-Board software, where users can browse and manage projects and associated panels. Here they can also start the whiteboard client and work on the panels content. The whiteboard client software can be started directly from the browser. It is not necessary to install anything, which makes it easily accessible from any computer.

2) Whiteboard Client: The Tele-Board Whiteboard Client is developed in Java as we were looking for a platform independent solution. Its main functions comply with standard whiteboard interaction: writing on the whiteboard surface with pens of different colors, erasing, and writing sticky notes. Additional functions as panning the whiteboard surface, cut and paste, clustering, deleting elements, or adding pictures enhance the working experience (see Figure 5).

3) Sticky Note Pad: As an equivalent to paper sticky note pads we created different applications for writing sticky notes.

Fig. 5. Screenshot of whiteboard client

The Java application is ideal for Tablet PCs and other pen input devices. For fast finger input you can use the dedicated App on an iPad, iPhone or iPod Touch. By creating the sticky notes digitally instead of capturing paper notes, media gaps and capturing time as in *The Designer's Outpost* [6] can be omitted.

4) Server Component: The Server Component coordinates all communication between the remote partners. It is possible to open various instances of the same whiteboard panel. All whiteboard elements and actions are synchronized between the whiteboard instances, enabling every user to always see the team members' actions and manipulate all sticky notes and drawings, no matter who created them. This is a major advantage compared to *Clearboard* [15] and *VideoWhiteboard* [27] where you can only manipulate your own whiteboard marks.

All components except for the Web application communicate using the Extensible Messaging and Presence Protocol (XMPP)[5], an XML-based protocol for message handling and routing. The description of every whiteboard element is translated to an XML representation and synchronized to the remote location. Using a protocol based on an open standard allows sending messages from very basic Internet-enabled devices such as mobile phones or smartphones without implementing any specialized communication software, since there are libraries for all common operating systems and programming languages. XMPP provides the participating components with the notion of multi-user chat rooms and fits fairly well into the Tele-Board system. In this way all whiteboard clients that start the same panel are connected. Whenever a user modifies something on this panel, the modifications are transferred to the other participants in the session via XMPP messages. When a whiteboard client receives such a notification from another client, the UI is updated accordingly. On mobile devices, the *sticky note pad* provides a user interface following the sticky note pad metaphor and allows the transfer of handwritten sticky notes to the whiteboard clients. Typically this will

[5] http://xmpp.org/rfcs/rfc3920.html, http://xmpp.org/rfcs/rfc3921.html

be the whiteboard client of the electronic whiteboard in the same room as the mobile user, but this is not required. When receiving such input via XMPP, the whiteboard client will send update messages, which are interpreted by all connected whiteboard clients. The data transfer can be transmitted via a standard internet connection (DSL), there are no special requirements.

All XMPP communication is processed by the Tele-Board server component. This server adds additional session management capabilities to the Tele-Board architecture which are not part of XMPP itself. It includes continuous archiving, restoring of panel content, and more advanced Tele-Board features that go beyond the sticky note and whiteboard metaphors on digital equipment, such as browsing through the history of a panel [9]. Web services can generate different kinds of information from the log data. For example, it is possible to render a screenshot in several graphics formats and arbitrary resolutions from any point in time. Another option is to visualize whiteboard activities in their temporal order.

B. Hardware Independence

Due to the average user's acquaintance with analog tools, supporting adequate input devices clearly is an important aspect of our work. In the last years not only sophisticated mobile devices (smartphones) such as Apple's iPhone or Google Android phones have emerged, but also the development of large scale touch-sensitive wall screens ("digital whiteboards") is fast-pacing.

In designing our system, we dealt primarily with two challenges: the selection of suitable off-the-shelf input devices for fast prototyping and early testing as well as the design and implementation of a flexible and extensible software framework for the various user interfaces.

Because we focused on working modes concerning collaborative whiteboard interaction and the creation of sticky notes on personal notepads, there was the minimum need to pick one digital whiteboard and a variety of mobile devices (phones, Tablet PCs etc).

The optimal digital whiteboard for Tele-Board would be very large but highly moveable, could recognize an arbitrary number of pointers working simultaneously (multi-touch), and could distinguish finger input from pen input. We tried out several different products: interactive whiteboards by SMART Technologies[6] and Promethean ActivBoard[7], the Luidia Inc. eBeam[8] - an easily portable device to support pen-input on arbitrary walls and also the work of Johnny Chung Lee [19], using Nintendo's Wii Remote technology to realize a low-cost multi-touch whiteboard. All of these devices and any devices supporting pointer input can be used with Tele-Board. Currently, we use the SMART Technologies interactive whiteboard ("SMART Board") as a compromise between feature richness and reliability.

[6]http://www.smarttech.com/

[7]http://www.prometheanworld.com

[8]http://www.e-beam.com

Because mobile input devices act as the digital equivalent of basic personal sticky note pads when running our software, we want to support as many systems as possible. We currently support iPhone OS natively and plan to adapt our software to devices of other platforms as soon as possible. Using open standards such as XMPP for the client/server communication has accelerated development due to existing libraries.

Another reason for using the open XMPP protocol is the availability of XMPP-capable chat clients for almost every imaginable platform – desktop operating systems as well as modern mobile platforms[9]. With these clients we were able to rapidly set up a first prototype of the overall system by using existing chat software as an input device. By this means, users can easily create sticky notes with the keyboard and send them to the whiteboard in form of a chat message. Especially for quickly entering large amounts of information users appreciated this way of creating sticky notes that has not been there before.

We designed an abstraction layer to decouple the different input devices and input types from our Whiteboard Client and Sticky Note Pad applications. The input abstraction layer defines four basic types of input signals: touch interaction with fingers, special device interaction such as pen or eraser, mouse and keyboard input, and a programming interface (API). The API allows the Tele-Board applications to access raw input data, e.g. x/y coordinates, value of pressed key, or color of pen. It can register observers for events triggered by the input devices, e.g. "mouse clicked", "finger down/up" etc. On the other end, the abstraction layer wraps the respective APIs of the physical input devices. Multi-touch gesture recognition can be implemented here as well.

As a starting point, we implemented adapters for the most generic input devices – mouse and keyboard. These adapters allowed usage of the whiteboard client on standard desktop or laptop computers. In order to obtain a higher sampling rate and accuracy, we also integrated the SMART Board API directly, including support for touch interaction with finger and pen and differentiation of pen colors. This more precise pen input enables a more natural feeling of writing on the whiteboard and personal sticky notepad application for any SMART devices with pen input, such as the SMART Sympodium.

C. Full-Body Video Conferencing

Prior work has shown that remote collaboration on electronic whiteboards benefits from an accompanying video conference showing the remote team interacting with their whiteboard [8]. Without video, whiteboard interactions by remote team members appear as if they were made by a "ghost hand". Thus, the Tele-Board system shall integrate with a video conferencing software. We wanted to focus on a reliable and cost-efficient video conferencing solution that does not impose additional entry barriers for users of the system. For the current implementation we decided to use Skype because

[9]see: http://xmpp.org/software/clients.shtml

of its popularity and proven reliability, but you could use other third-party video conferencing software as well.

When the video transmission screen area is separated from the whiteboard content, it is difficult to see pointing gestures of the remote team. Therefore, the Tele-Board whiteboard client was designed as an translucent overlay on any video conferencing software. This way, you can see the remote party directly interacting with the whiteboard content. They even seem to touch your local whiteboard elements (see the video at http://tele-board.de for a demonstration).

Fig. 6. Tele-Board system setup (angular camera position)

The video cameras can be positioned next to the electronic whiteboards, capturing the foreshortened whiteboard and the people in front of it (see Figure 1, 6 and 7, angular position). This way, people can face both the whiteboard and the camera at the same time. However, this set-up comes with the trade-off that due to the camera angle on the electronic whiteboard, the screen area that can be used for the Tele-Board whiteboard client is roughly reduced by half (see Figure 6).

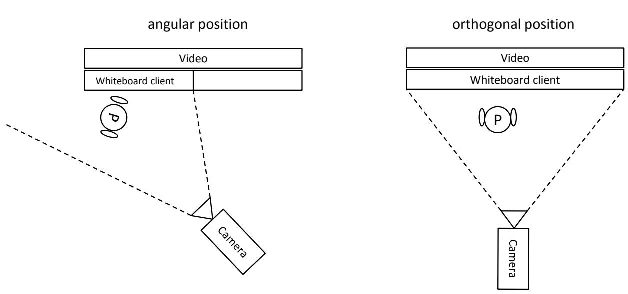

Fig. 7. Different camera setups

Another possible setup (see Figure 7, orthogonal position) uses a camera position directly in front of the whiteboard capturing the whole whiteboard surface almost without any skewing and no loss of whiteboard space. The person standing in front of the board is shown from behind. Eye-contact is limited using this setup, but the perception of pointing gestures is optimal with this setup. The user also has more room between whiteboard and camera and can act more freely.

V. Summary and Future Work

In this paper we presented Tele-Board, a groupware system specialized on creative working modes using the traditional whiteboard and sticky notes metaphor. In the beginning we focused on synchronous team work with special focus on distributed settings, as we observed a general need for a well-suited solution. However, Tele-Board also supports co-located teams by offering digital advantages such as saving whiteboard states, changing sticky notes size and color or expanding the whiteboard space with the panning function. In the future we want to augment the Tele-Board system with other functions, which supports designers in fulfilling their work and especially help them with difficult tasks during the process. One of these difficult tasks could be the handling of large amounts of user research data and to decide which information is most relevant and should be integrated in the final design. We found out that the *research synthesis* and the associated conversion of knowledge [7], [22] are considered the most crucial times during a design process. Interviewees and test participants as well as other designers [17] stated that it is imperative to establish a common understanding of the research results. We believe that digital tools can support designers in this complicated phase. With our current system, it is already possible to rearrange and cluster sticky notes in order to classify research or brainstorming results. The clustering could be enhanced by other visualization techniques such as mind-maps, flow-charts or other kinds of diagrams [1], [17]. Which instruments best support this phase is currently investigated through observations of design teams and interviews with people involved in the research synthesis.

As we learned from feedback on our current system, it is not only important to enable synchronous working modes for distributed design teams, but asynchronous collaborative work as well. To address the problems of design teams who are working asynchronously over distances, we developed the Tele-Board history browser: a web-based interface giving the opportunity to go back and forth in the timeline of a whiteboard [9]. It enables the designer to view the collected data from different perspectives and thereby gain a deeper understanding of the project context. The team can also continue at any past state by duplicating the whiteboard content, i.e. starting a parallel session. All data is persisted implicitly, meaning that users do not need to think about saving their data. In the future, we want to use this data to e.g. identify important project phases in design sessions of several hours or search for relevant information. With the collected data we want to investigate how it can ease the hand-over process of asynchronously working teams. Therefore, a computational understanding of the collected data must be achieved in order to detect structures in the design process and find the most important points in time during a design session.

The analysis of design activity in general is an important topic, but until now it has been difficult to collect data of different design teams at work [5], [20]. The *iLoft project* already offers collaboration and information technology to design teams to study their design activity [20]. Much of the reporting and evaluation of data has to be done manually, which is a very time consuming process. With future versions of Tele-Board we could automatically generate documentation and reporting data such as presentation slides (e.g. for customers and managers) or statistical analysis of design activities for design researchers.

Above all, our next steps involve the evaluation of our system by different users. During development we already collected qualitative feedback on the interaction design of the system, which helped us to improve the usability of the system. At the moment we are planning a comparative study where students are supposed to work with the Tele-Board either with a video conference or only with an audio connection. Moreover we already scheduled a longterm study where students will use Tele-Board over several months. We will observe their usage of the system and have them evaluate how much it improves their communication compared to other collaboration tools.

The Tele-Board prototype allows us to demonstrate that it is possible to collaborate over distances and still employ creative working methods. Forthcoming research will concentrate on enhancing the system for synchronous and asynchronous working in distributed and co-located settings. With Tele-Board we bring remote collaboration closer to face-to-face communication, while retaining all advantages of the digital world.

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