# Tele-Board: Enabling Efficient Collaboration In Digital Design Spaces Across Time and Distance

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**Abstract** Design Thinking is an approach for innovative problem solving. A typical characteristic of this approach involves multidisciplinary teams and the extensive use of tangible tools such as sticky notes, whiteboards and all kinds of prototyping materials. When team members try to collaborate from separate locations their traditional way of working becomes nearly impossible. A number of computer supported collaborative work systems exist, but there still lacks acceptable support for teams applying methods like Design Thinking. We have created an environment that allows these teams to work together efficiently across distances, without having to change their working modes. The Tele-Board prototype combines video conferencing with a synchronized whiteboard transparent overlay. This unique 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. User feedback has confirmed that the Tele-Board system is a good basis to further enable collaborative creativity across distances while retaining the essential feeling of working together.

## 1 Creativity Across Distances: Can We Make It Work?

Collaborative creative work is done best in co-located settings. People communicate with each other face-to-face, see each other's gestures and facial expressions, and directly manipulate all involved artifacts. Sticky notes, whiteboards, walls, pens, all imaginable handicraft objects, role-play and storytelling may all be used when creative methods such as Design Thinking are applied [1]. Bringing together the insights of research and different perspectives of a diverse team is a key factor for

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successfully fueling innovation. In order to incorporate different cultural aspects as well, international teams are 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 act as a comparable option to analog tools for teams using Design Thinking?

Discovering answers to these questions has been the objective of our project within the HPI – Stanford Design Thinking Research Program. We saw that Design Thinking teams at the Hasso-Plattner-Institute of Design at Stanford (d.school) and the HPI School of Design Thinking create successful products and concepts. Furthermore, the Design Thinking methodology is used at several design companies [2] and examples prove that it leads to successful results [1]. This kind of work, which is very different from standard office work, has a high potential for creating innovations in different industries. But we all know that in a globalized world development does not take place at only one location. Thus our vision emerged to enable people located at different parts of the world to work together as naturally and smoothly as they are accustomed to in their current environment.

A number of tools supporting remote collaboration already exist. For nearly 20 years research has been done to enable people to communicate and share artifacts across distances. In the last years, commercial products for remote collaboration also 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, as shown by our evaluation of existing tools for remote collaboration. Most tools only support standard desktop work and are cumbersome to use in general [3]. In order to really meet the requirements of real-world Design Thinking teams we started by interviewing teams at the HPI School of Design Thinking and at SAP's Design Services Team and observing them in their workspace. We wanted to find out how people work with each other and how they interact with all involved artifacts. Our research resulted in identifying seven main Design Thinking working modes.

From these conclusions we decided to design and implement a new IT-tool which truly supports and optimizes collaborative creative work without getting in the way of the teams involved in the process. Recent development of touch enabled whiteboards, monitors and smartphones provided us with new opportunities for an intuitive use of hard- and software. Hence, we started to develop the Tele-Board system, an electronic whiteboard software suite which allows users to write digital sticky notes on tablet PCs, smartphones or directly on a whiteboard. Users 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 included a video conference among the distributed team. The translucent whiteboard can be displayed as an overlay on top of a full screen video of the other team members (see Fig. 1). This setup lets everyone see what the others are doing, where they are pointing along with their gestures and facial expressions.

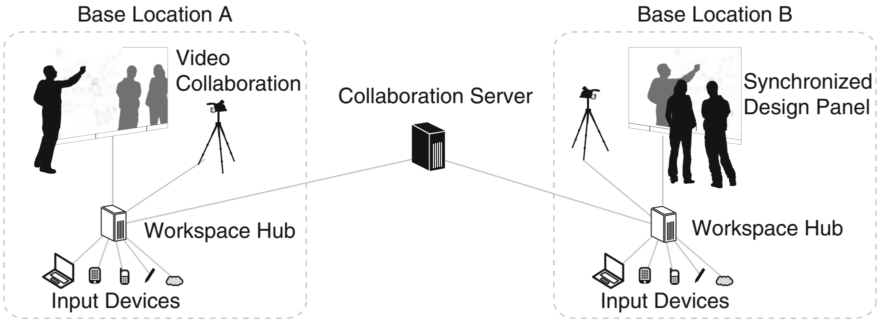


**Fig. 1** Setup of the current Tele-Board prototype

In the following, we will present our findings on the Design Thinking working modes, describe the Tele-Board system and its architecture, and discuss user feedback we received in experiments and interviews. The chapter closes with an outlook on the following project year and further research topics.

## 2 Analyzing Design Thinking Working Modes

In order to formulate requirements for our tools, we needed to understand the way Design Thinking research teams work and interact, and anticipate what they would demand of an IT-tool aimed at supporting them. We observed and interviewed teams at the HPI School of Design Thinking and SAP's Design Services Team. Through our observations we found out that users have different needs in different situations. To classify these users' needs we identified seven working modes (see Fig. 2) which we consider the most important for Design Thinking. Of course these modes may be expanded by other modes as working techniques vary by organization and group.

The different working modes and their specific characteristics are the following:

**Handwriting and drawing on a whiteboard.** This working mode happens often and for various reasons during a design session. Some examples might be: noting facts or ideas, visualizing an idea or a process through rough sketches, or drawing a diagram to explain relations. Multiple colors and an eraser may be used, as well as printouts of pictures and other information. It is important that the whiteboard stands vertically to be seen easily by fellow team members. Each team member must have direct access to the whiteboard. Gestures are frequently used to support communicating an idea to other team members.

**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 immediately or during a quick presentation phase. Differently colored sticky notes are used to keep track of the information's source. It is important

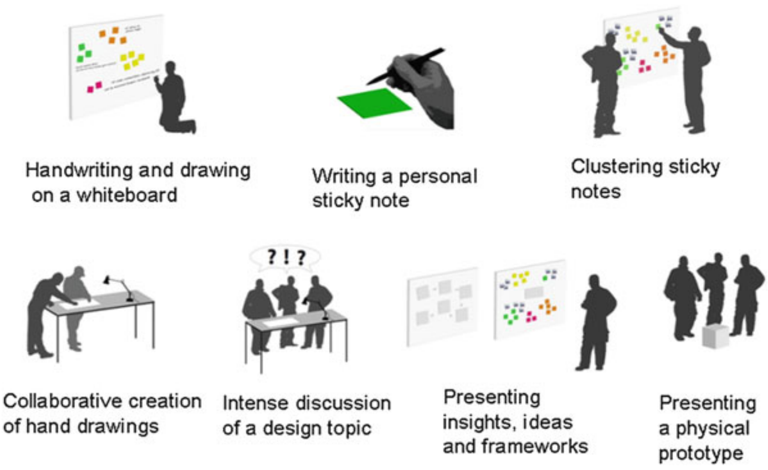


**Fig. 2** Working modes during Design Thinking projects

that sticky notes are relatively small so that team members use them to record only a single, concise fact or idea that can be grasped at a glance. It must be possible to write sticky notes on a horizontal surface to ensure comfortable writing and scribbling.

**Clustering sticky notes.** Usually, one or two team members stand in front of a whiteboard and cluster the team's sticky notes. A cluster is often defined by circling sticky notes with a whiteboard marker and applying a label. Other team members may instruct them from a distance. The team tries to group related research information or ideas that were generated during a brainstorming session. Moving sticky notes around must be easy, and all team members should be able to see each other's pointing gestures, as the whole group should find the best cluster representation together.

**Collaborative creation of hand drawings.** Often one person draws a design object 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. A horizontal setup is generally preferred to make drawing more comfortable.

**Intense discussion of a design topic.** The team meets to discuss a topic related to design artifacts, which are often laid out on a table. Visibility of team members' gestures, facial expressions and eye contact as well as related artifacts is crucial.

**Presenting insights, ideas and frameworks.** This working mode often involves a bigger audience. It is important to collect as much feedback as possible from the audience. The team uses design artifacts created in their team space mostly presented on a whiteboard using a vertical setup.

**Presenting a physical prototype.** For this working mode it is necessary to present a physical object from all sides. It might also include acting out an idea. Similar to the preceding working mode, an audience is involved.

The first three working modes (handwriting on a whiteboard, writing a sticky note and clustering) are essential for creative processes such as Design Thinking, and most suitable to be implemented in a digital solution. Therefore we aim to support working on a whiteboard with sticky notes, handwritten text, drawings and clusters. For distributed settings it is obvious that a digital representation of a whiteboard simplifies collaboration on design artifacts by all team members in all locations. It is necessary to support the visibility of gestures and facial expressions of team members in addition to hearing their voices.

## 3 Evaluating Existing Tools for Remote Collaboration

In the following we give a brief overview of existing full-fledged tools that are designedto support remote collaboration in the creative processes we evaluated. We considered commercial tools as well as some interesting scientific ideas and prototypes that make no claim to be complete. As a result of this evaluation we recognized that recent solutions do not realize the full potential that Internet and web technologies can contribute to support creative remote collaboration.

**Commercial Products** There are a variety of tools on the market which offer possibilities for collaboration between dispersed teams. However, most products focus either on video conferencing capabilities or on sharing artifacts. A commonly used tool that offers both functions is Adobe Acrobat Connect Pro,[1] formerly Macromedia Breeze, which is mainly a web-based conferencing system and so-called learning environment. It features the most common tasks in a meeting setup, such as audio and video conferencing, screen sharing and a simple whiteboard solution. Workspaces are called "pods" each with a specialized role (whiteboard, chat, etc.). Here lies the main drawback of the system: The integration between these components is insufficient. For example, pointing to certain parts of a sketch on a whiteboard is impossible in a video conference. Interviews with SAP, an intensive user of this software product, showed that most of the functionality is hardly used, such as the whiteboard component.

Telepresence systems such as those provided by Cisco[2] or Polycom[3] 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 suitable for big companies. Telepresence systems are basically an arrangement of hardware components. The best setup makes it possible to build up a virtual meeting room,

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

[2] http://www.cisco.com/en/US/netsol/ns669/networking_solutions_solution_segment_home.html.

[3] http://www.polycom.com/products/telepresence_video/telepresence_solutions/index.html.

so everyone in the meeting has the illusion of sitting together at the same table. A major drawback is the lack of integrated support for whiteboard interaction.

There are several commercial and non-commercial websites on the Internet which focus on enabling users to sketch ideas on digital whiteboards.[4] They all provide simple means to draw sketches and share them with colleagues. Real-time collaboration on the whiteboard is not supported and would be difficult to attempt, because none of these solutions offer support for audio or video conferencing.

What all of these solutions have in common is that they do not support the users in actual collaboration with each other. People cannot properly sketch their ideas and discuss them with remote partners. Because of this, an emotional disconnect is built up between the communicating partners.

**Scientific Prototypes** The first tools to support creative collaboration of spatially separated teams were *VideoDraw* [4], *VideoWhiteboard* [5] and *Clearboard* [6], 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 the drawings from one side on the other. VideoWhiteboard more closely fits the requirements of our working modes, as it transfers whiteboard content with the help of rear projection to the whiteboard of a remote person. Additionally, a shadow of the entire upper body of the remote person is transferred to see the 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 [5]. Even more importantly, one cannot manipulate the other persons drawings or show physical artifacts. This drawback also arises with the Clearboard system, although it is possible to see a real image of the other person rather than only a shadow.

Everitt et al. [7] also used shadows to mimic the remote person's presence. They augmented *The Designers Outpost* from 2001 [8], a collaborative tool for website design. Users apply digital sticky notes to sketch the 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 they would move a sticky note. The transient ink arrow disappeared after several seconds. The Designers Outpost hereby presented a very promising approach to work 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 is not always used. Additionally, the system would need audio support for a real remote setup.

Another project with similar ideas is *Video Arms* [9] from 2006, which uses digitalization of arms to enable pointing in a remote setting. A computer vision approach is used to capture the arms of the people working, cut them out of the video image,

[4] cf. http://skrbl.com, http://thinkature.com and http://imaginationcubed.com.

and then reinsert a translucent version on both the remote and local screens. 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. [10] 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. The questions remains open as to how this holistic digital environment approach could be transferred to a distributed location setup, as it has only been implemented in co-located settings.

All aforementioned systems offer interesting functions for remote collaboration, but each of them also shows drawbacks, especially when used to support creative collaboration. Our goal is to overcome these drawbacks with our Tele-Board system, as described in the following section.

## 4 Our Tool: Tele-Board – A Digital Whiteboard for Remote Collaboration

The Tele-Board system aims at providing designers and researchers with a software suite to pursue the Design Thinking working modes we identified using digital hardware devices. It supports working over distance and under certain restrictions, such as being forced to interrupt and resume work at a different time or place. Tele-Board simulates whiteboard content like sticky notes and supports handwriting on electronic whiteboards. This 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. User interaction on one electronic whiteboard should both influence the local and the remote whiteboard. Preliminary research has shown that such remote interaction should be accompanied by video transmission of the participating users, which provides remote whiteboard modifications with a human context. To overcome physical limitations of today's electronic whiteboards, and to support the working modes identified, Tele-Board also needs to support additional input devices other than electronic whiteboards. Hand-written notes play an important role in Design Thinking projects. In a digital setup, this can be achieved using pen enabled or touch enabled laptop computers and mobile phones. These devices can then be used to write sticky notes in a private environment. From these devices, users have to be able to transmit sticky notes to an electronic whiteboard.

Next, the general architecture of these components is presented, followed by an introduction to the server component which mediates content between devices. Also, we present results of our research on mobile input devices in the context of Tele-Board, and show how different video conferencing approaches can be integrated into the Tele-Board system.

### *4.1 Tele-Board: General Architecture*

The Tele-Board architecture clearly separates objects and concepts taken from the Design Thinking domain from the computer software and hardware involved. We will present the data model derived from these Design Thinking concepts, the users interaction with the data model through physical hardware devices, and the software components facilitating data exchange between different devices and locations.

All activities in the Tele-Board software are centered around *projects*. A project can comprise all phases of a Design Thinking activity and can endure several months. During a traditional Design Thinking project, a fixed set of analog whiteboards is 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, but can be archived and restored, and an unlimited number of empty panels can be requested. The panels themselves can be filled with various *whiteboard elements*, such as sticky notes or handwriting.

Panels are viewed and modified through electronic whiteboards, which are connected to a dedicated presentation computer. Decoupling whiteboard hardware and the whiteboards content using the notion of panels adds flexibility, as potentially only one electronic whiteboard is needed to replace a traditional setup with multiple analog whiteboards, and a larger number of panels can be worked on. In addition to direct manipulation of a panel displayed on an electronic whiteboard, Tele-Board allows for indirect user input from mobile and special devices, such as mobile phones or laptops, preferably with touch or pen input.

The mapping of the Tele-Board data model onto these hardware devices is achieved by using the Tele-Board software, which consists of four components: a *whiteboard client*, a *sticky note pad*, a *server component*, and a *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, and start working on such panels by opening them on an electronic whiteboard. All components except for the web application communicate using the Extensible Messaging and Presence Protocol (XMPP), an XML-based protocol for message handling and routing. Using XMPP for synchronization of whiteboard content is a common approach.[5] The description of every whiteboard element is translated to an XML representation and synced to the remote location. Using an open protocol allows the sending of messages from very basic Internet-enabled devices such as mobile phones or smart phones. XMPP provides the participating components with the notion of sessions and users and fits fairly well into the desired Tele-Board ecosystem. Each electronic whiteboard is managed by the Tele-Board whiteboard client installed on the computer attached to the whiteboard hardware. Whenever a user modifies a panel

[5] http://coccinella.sourceforge.net/docs/MemoSVG_XMPP.txt.

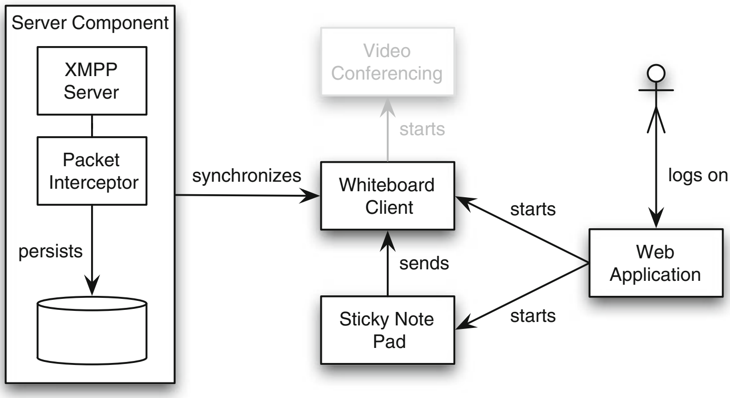


**Fig. 3** Conceptual model of system components

opened in such whiteboard client, XMPP messages reflecting the modifications are generated and routed to the other participants in the session. When the whiteboard client receives such XMPP messages from other components, the electronic whiteboard is updated accordingly. On mobile devices, the sticky note pad component provides a user interface following the sticky note pad metaphor and allows the sending of handwritten sticky notes via XMPP to a specific whiteboard client. Typically this is the whiteboard client of the electronic whiteboard in the same room as the mobile user, but this is not a requirement. After receiving such input via XMPP, the whiteboard client will send update messages to the other participants' whiteboard client. All XMPP communication is processed by the Tele-Board server component. This server component adds additional session management aspects to the Tele-Board architecture which are not part of XMPP itself. These aspects include storing and restoring panel content, and more advanced Tele-Board digital features that go beyond the sticky note/whiteboard metaphor (see Fig. 3).

## *4.2 Tele-Board: Server Component*

When participants are working on a panel using the Tele-Board system, XML representations of whiteboard elements transmitted to other participants are routed through the Tele-Board server component. In the server component, they are distributed to the recipients and are also stored for future history functionality in the XMPP server environment. The server-based components make it possible to interrupt and continue different sessions, and also to store the data to identify certain patterns of interaction.

The Tele-Board server component consists of two main parts: the plug-in for the Openfire XMPP server and a set of web services to process and visualize the history data. The plug-in encapsulates the stored history data and separates this from message routing in the XMPP server. The server plug-in is realized as a so-called packet interceptor. Each incoming message is read and parsed by the plug-in to decide how it should be treated. There are two possibilities: A message can be stored in the history data and forwarded to the recipients, or it can trigger an action and be prevented from being delivered to the other participants. The former case is used for every whiteboard exchange message, and occurs much more often than the latter, which is used for remote procedure calls to the XMPP server, e.g., to request the current whiteboard state upon application start-up. A sticky note updating its position will be logged to the history and the message will be delivered to the original recipients (e.g., the partner whiteboard client).

The data model used for storing the historical information is very basic. It is roughly a plain log made up of rows including the following: an object-identifier, a time stamp, a panel identifier, an action-code (such as NEW, CHANGE, DELETE), and XMPP-payload data describing the current object. This data structure provides a good trade-off between flexibility to reuse the data and detail of information. With this structure, every point in time and every creation, change or deletion of a whiteboard artifact can be reconstructed. That way, not only the latest state of a panel can be transmitted to whiteboard clients, but upon request older states can also be restored from the history database and viewed on a whiteboard client.

The web services can generate different kinds of information from the log data. 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, including certain annotations such as whiteboard-clearing events, or to generate an overview of multiple charts that belong to one project and arrange them in their temporal order.

### *4.3 Tele-Board: Input Devices*

Due to the average user's acquaintance with analog tools, supporting adequate input devices is clearly an important aspect of our work. Even rudimentary market studies show that development is increasing more rapidly than ever before. Not only sophisticated mobile devices, like smart phones such as Apples iPhone or recent Google Android phones, have emerged, but also the development of large scale touch-sensitive wall screens (digital whiteboards) has picked up. Convertible tablet PCs are making a comeback, with larger displays and multi-touch gesture support.

We dealt primarily with two deriving challenges:

- The selection of suitable off-the-shelf input devices for fast prototyping and early testing
- The design and implementation of a flexible and extensible software framework for the various user interfaces

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

The optimal digital whiteboard would be very large but highly moveable and collapsible, could recognize an arbitrary number of pointers working simultaneously (multi-touch), and could distinguish finger input from pen input. Throughout our first year, we evaluated several product classes:

- SMART Technologies interactive whiteboard,[6] a stationary digital whiteboard screen for projectors that recognizes fingers and different pens
- SMART Technologies interactive display frame,[7] a touch-sensitive overlay for large plasma TVs, allows for dual-touch gestures
- Luidia Inc. eBeam,[8] a highly mobile device that can be used on arbitrary white walls, but only supports stylus input
- Promethean ActivBoard[9] series, a line of high resolution stationary digital whiteboards that support two pens simultaneously, but no finger input

We chose the SMART Technologies interactive whiteboard (SMART Board) as a compromise between feature richness and reliability. Its drawbacks can be disregarded for our project, as vendors will release more technically mature devices supporting multi-touch or dual-touch gestures.

Discussions on the work done by Johnny Chung Lee,[10] who uses Nintendos Wii Remote technology to realize a DIY multi-touch whiteboard, encourage us to consider this approach in future. System advantages would include lightweight implementation, thus better mobility, very good cost ratio and multi-touch capability.

Because mobile input devices act as the digital equivalent of basic personal sticky note pads when running our software, we decided to support as many systems as possible. Software for smart phones running iPhone OS, Android, Java Mobile Edition, Windows Mobile, and Symbian OS are planned to be available over time. This highlighted the need for platform-independent development and the usage of open standards wherever possible.

One example benefit of the open XMPP protocol standard is the availability of XMPP-capable chat clients for most existing platforms, as well as for all broadly used desktop operating systems and modern mobiles.[11] With these clients we were able to rapidly set up a first prototype of the overall system by only implementing the whiteboard client. Users can easily send messages from their personal smart phone using the respective instant messenger to chat to the whiteboard. The text appears on the board as written on sticky notes. Furthermore, the existing XMPP libraries for all common programming languages can be used for communication within the D-Tools 2.0 software suite. We designed an abstraction layer to decouple the different input devices and input types from our whiteboard client and sticky note pad applications (see Fig. 4).

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[6] http://corporate.smarttech.com/products/SMARTBoards.aspx.

[7] http://corporate.smarttech.com/products/displayframe.aspx.

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

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

[10] http://johnnylee.net/projects/wii.

[11] http://xmpp.org/software/clients.shtml.

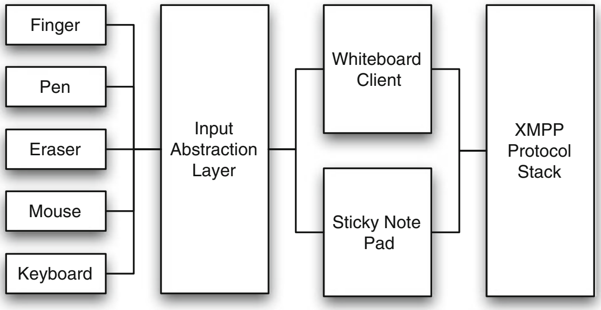


**Fig. 4** Tele-Board input abstraction layer architecture

The input abstraction layer defines five basic types of input signals: touch interaction with fingers, special device interaction with a pen or eraser, and mouse and keyboard input. A programming interface (API) is also available. The API allows Tele-Board applications to access raw input data, e.g., x/y coordinates, the value of a pressed key, or color of a pen. It can register observers for events triggered by the input devices, e.g., mouse clicked or finger down/up. From the other end, the abstraction layer wraps the respective APIs of the physical input devices. Multi-touch gesture recognition will be implemented here.

The layer also enables the negotiation of parameters of input devices. For example, does it support finger and/or pen interaction? Does it support multi-touch or single-touch? How many buttons and colors are available? Applications can adjust their user interface according to the capabilities of connected devices.

This abstraction will allow us to integrate future digital whiteboard devices by just implementing a new interface. There will be no need to change any of the Tele-Board applications.

As development began, we implemented rudimentary adapters for the most generic input devices, namely mouse and keyboard. These adapters allowed usage of the whiteboard client on usual desktop PCs or laptop computers. Within the first year, we also finished the integration of the SMART Board API supporting touch interaction with finger and pen and differentiation of pen colors, as well as the personal sticky note pad application for tablet PCs and other devices with pen input, e.g., the SMART Sympodium. More devices such as smart phones will be integrated in the next project phase.

## *4.4 Tele-Board: Video Conferencing and Remote Full-Body Gesture Overlay*

Preliminary work has shown that remote collaboration on electronic whiteboards benefits from an accompanying video conference showing the remote team interacting with their whiteboard [11]. Video eliminates the problem of having whiteboard interactions by remote team members appear as actions made by a ghost hand. The Tele-Board system has been designed to support video conferencing from the beginning. This saves its users from well-known hindering factors and allows a clearer evaluation of the system's support for design thinkers. For our project, we wanted to focus on a reliable, cost-efficient video conferencing solution that does not impose additional entry barriers. For the current implementation we decided to use third-party video conferencing software such as Skype[12] because of its popularity and proven reliability.

Instead of separating video transmission screen areas from whiteboard content, the Tele-Board whiteboard client can overlay any video conferencing software in a translucent way to give the impression that the remote party is directly interacting with local whiteboard content. The video cameras can be positioned next to the electronic whiteboards, capturing the foreshortened whiteboard and the people in front of it (see Fig. 1). With this setup, people can face both the whiteboard and the camera at the same time. However, it 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 Fig. 5). If the camera were to be pointed directly at the whiteboard to capture a flat image of it, the people at the board would naturally be shown from behind, which would reduce the communication experience between remote participants.

**Fig. 5** Tele-Board remote system setup

[12] http://www.skype.com.

## 5 Tele-Board: User Feedback

During the whole process of prototype development, our goal was to minimize users' notice of the system's digital nature. To evaluate our success in fulfilling this intention we often asked colleagues with different scientific backgrounds to try out the system and give feedback on whether it felt natural to work with. Midway through the development phase we conducted a qualitative study with ten participants who had never heard of the system. All of them came from different educational backgrounds and have experience from the HPI School of Design Thinking. With the help of the study we wanted to understand how comfortable users are with different input devices, how the interplay between input devices and whiteboards works and how the general usability of the digital whiteboard was. As the study was specifically about whiteboard and input devices we did not include a video conference at this point.

Prior to the practical tests we asked the participants about their general behavior of writing sticky notes and applying them to a real whiteboard. We asked if they could imagine writing sticky notes with a digital device and about how important pen and paper were to them. Subsequently, the participants were asked to write sticky notes with a digital pen directly on the whiteboard and with a digital device similar to a tablet PC which sent them to the digital whiteboard. At this stage of development, our research prototype did not yet support digital pens. Hence, we used the Wizard of Oz method [12] to simulate it. Users wrote down their ideas on real sticky notes and hit a fake buzzer to send them. Simultaneously, a team member standing by with a laptop typed out the written message in a chat program and sent it. Afterwards the participants tried out all interactions we implemented in the whiteboard so far, such as moving, deleting and clustering sticky notes (see Fig. 6).

About half of the participants stated in the beginning that they would prefer using paper and pen over a digital device and kept their opinion after trying out the two different options. However, nearly all of them said that they would prefer the digital version if it was as fast and safe as paper and pen. Digital hardware and software are still not as precise and smooth as pen and paper, and people generally prefer analog artifacts for fear of data getting lost. Some users stated that they would not want to deal with a digital sticky note in addition to an analog one, as this might lead to confusion and eliminate the advantage of saving paper. Participants also emphasized

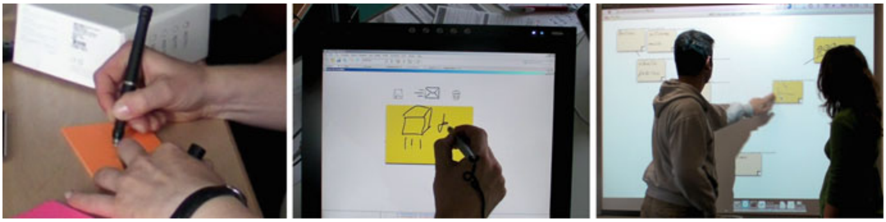

**Fig. 6** Different tasks at qualitative user feedback study

that they could imagine using the digital version if it supported a wider range of standard computer system advantages like saving different versions, loading at any time or advanced documentation functions.

With regard to the interplay of input devices and whiteboard, we learned that a serious limiting factor of the digital sticky note pad application was its inability to determine where the sticky note would appear on the whiteboard. Users expressed that they either wanted to directly control where it would appear on their device, or would want to stand directly in front of the whiteboard with a portable device, so they could move the sticky note right after sending it. Concerning general usability the study also helped us to identify and improve various usability issues.

Using the input of this study we developed a next version prototype which we presented at the International Conference on Engineering Design (ICED) 09 at Stanford University and the Mensch und Computer 09 conference at the Humboldt Universität Berlin [13]. At both conferences the whole system was used, including videoconference between two whiteboards. In Stanford the audience participated by writing their own sticky notes; in Berlin our team gave a demonstration and members of the audience stood by to observe.

At both presentations the audience was enthusiastic about the combination of video and transparent whiteboard and the realistic feeling it conveyed. The ability to point at sticky notes and still keep talking to the remote partner was especially appreciated. Nevertheless, the video overlay was not very accurate yet and has to be improved. Participants also remarked that the whiteboard space is very small when using half of the space for the video. The restricted space on the whiteboard is clearly an important topic we have to concentrate on. When participants were involved in writing sticky notes at ICED09 we also noticed performance issues with our system. The more sticky notes were posted to the whiteboard the slower the reaction of the system was. It was difficult to move sticky notes around, and writing on the whiteboards became cumbersome. Since then we have solved many performance problems, but there is still room for improvement.

## 6 Outlook and Future Work

Findings of the first project year revealed many advantages of a digital solution applicable *not only* to distributed team settings. For example, in the physical world it is not possible to go back to different whiteboard states, and documenting can only be done by taking pictures of the analog whiteboards.

Existing research on computer supported collaborative work divides the topic into four parts, each demanding different requirements of tools [14]: The two defining factors are working synchronously vs. asynchronously and working in a co-located team vs. a distributed team (see Fig. 7).

Synchronous, co-located Design Thinking (Fig. 7c) is the preferred way for ideation and synthesis phases where it is important to directly communicate ideas and see the reactions of team members. Synchronous communication usually takes

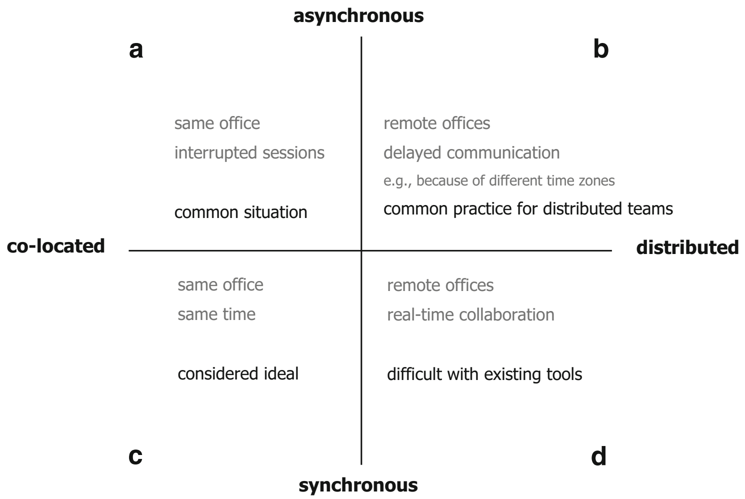


**Fig. 7** The four dimensions of collaboration

place in co-located settings, because communication between distributed team members (d) is often troublesome with most existing tools. Asynchronous Design Thinking is especially important if time zone differences only allow a minimum number of overlapping working hours (b). Distributed teams define separate tasks and need to continue work where their partners left off. In this setting it is important to find out what has been done, i.e., have constant, easily accessible documentation of the other team's work, ideally created with minimal effort. Asynchronous communication also happens in co-located settings (a), e.g., if people work on different projects or other constraints don't let them work together. The requirements of a tool to support this are the same as in distributed settings. To narrow down the focus for our project we started by supporting synchronous and distributed Design Thinking sessions (d). The result is our Tele-Board system.

At the HPI School of Design Thinking, and especially in industry, gaps between source materials (files, printouts, media) and created artifacts from Design Thinking methods proved problematic. The same gap exists between Design Thinking results and documentation, needed for archiving or reporting to stakeholders. Working in a digital environment creates potential for retaining links from information artifacts that evolve from the methods of Design Thinking back to their original sources. It also allows enrichment of all items with metadata. This is the foundation to support generation of documentation and report files, such as presentation slides or statistical analysis with visualization. How to support both advanced workflows for Design Thinking projects and the generation of associated documentation, while still remaining very adaptable to the specific project context, is a future research topic for D-Tools 2.0.

Being able to go back and forth on the timeline and along the links between information artifacts enables the design thinker to view all gathered data from different perspectives and thereby gain a deeper understanding of the project context.

This will also help the team analyze the overall project progress and decision paths taken by the respective distributed sub-teams or by the team itself in earlier project phases. Additionally, the team can continue at any earlier state by branching whiteboard content. Further improvements might be achieved by detecting relevant time periods (hot spots), i.e., when project-critical decisions take place. Identification of those hot spots can help distributed teams working asynchronously when handing over their daily project progress to the remote team – for example by simply speeding up or even skipping the history playback between the hot spots.

Through our research in the first project year we found out that the synthesis phase is considered the most crucial part during a design process. Interviewees and test participants as well as other designers [15] stated that it is imperative that a common understanding of the research results is established. Only then the most important problems can be identified and addressed through iterations of the evolving design. Practical design thinkers claimed that synthesizing is already complex in co-located settings, and is hardly even possible for distributed teams.

We believe that digital tools can support designers in this complicated phase. With our current prototype 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 to create a common understanding by jointly creating data models such as mind-maps, flow-charts or other kinds of diagrams [15, 16]. Which tools would best support the synthesis phase must be investigated through observations of design teams and interviews with experienced design thinkers. The ideas triggered by our observations will be implemented and tested on our current prototype to find out which concepts work to improve the synthesis phase. All insights we gain through observation and testing can be valuable for the research on Design Thinking process phases. We want to investigate how important different types of visualizations are in the context of converging information and how they can be best applied to interactive tools.

In the next project phase we will conduct a user testing at the HPI School of Design Thinking and ask the students to use Tele-Board for their current projects. Thereby we want to understand how well a digital whiteboard system can be incorporated into a traditionally analog style of working like Design Thinking. Other interesting questions related to this study are: What impact does a digital system have on the whole process and on the team dynamics? Will people write more or less sticky notes, and does this have an impact on the creation of ideas? Does the system help structure and document ideas?

The Tele-Board prototype allowed us to demonstrate that it is possible to collaborate over distances and still employ creative working methods. Tele-Board provides digital support without being tied to the traditional desktop. It integrates life-size video with simultaneous manipulation of artifacts on a whiteboard. Forthcoming research will concentrate on enhancing the system for synchronous and asynchronous working in distributed and co-located settings. With this we bring remote collaboration closer to face-to-face communication while retaining all advantages of the digital world.

## References


1. Brown, T.: Design Thinking. Harvard Business Review (June) (2008) 84–92
2. Lindberg, T., Noweski, C., Meinel, C.: Zur Entwicklung eines explorativen Forschungsansatzes zu einem überprofessionellen Modell. In: Stein, E.K., Walzel, F., eds.: Oberflächen/Untersichten, Neuwerk, Zeitschrift für Designwissenschaft, Volume 1, pages 47–53 (2009)
3. Herrmann, T.: Design Issues for Supporting Collaborative Creativity. In: Proc. of the 8th Int. Conf. on the Design of Cooperative Systems, pages 179–192 (2008)
4. Tang, J.C., Minneman, S.L.: Videodraw: a video interface for collaborative drawing. ACM Trans. Inf. Syst. **9** (1991) 170–184
5. Tang, J.C., Minneman, S.: VideoWhiteboard: video shadows to support remote collaboration. In: Proc. of the SIGCHI conference on Human factors in computing systems: Reaching through technology, pages 315–322, ACM, NY, USA (1991)
6. Ishii, H., Kobayashi, M.: ClearBoard: a seamless medium for shared drawing and conversation with eye contact. In: Proceedings of the SIGCHI conference on Human factors in computing systems, Volume 92, pages 525–532, ACM, NY, USA (1992)
7. Everitt, K., Klemmer, S., Lee, R., Landay, J.: Two worlds apart: bridging the gap between physical and virtual media for distributed design collaboration. In: Proc. of the SIGCHI conference on Human factors in computing systems, Number 5, pages 553–560, ACM, NY, USA (2003)
8. Klemmer, S.R., Newman, M.W., Farrell, R., Bilezikjian, M., Landay, J.A.: The designers' outpost: a tangible interface for collaborative web site. In: UIST '01: Proc. of the 14th annual ACM symposium on User interface software and technology, pages 1–10, ACM, NY, USA (2001)
9. Tang, A., Tory, M., Po, B., Neumann, P., Carpendale, S.: Collaborative coupling over tabletop displays. In: Proc. of the SIGCHI conference on Human factors in computing systems, pages 1181–1190 (CHI 2006) (2006)
10. Hilliges, O., Terrenghi, L., Boring, S., Kim, D., Richter, H., Butz, A.: Designing for collaborative creative problem solving. International Conference on Creativity and Cognition, Washington, DC, USA (2007)
11. Fussell, S.R., Kraut, R.E., Siegel, J.: Coordination of communication: effects of shared visual context on collaborative work. In: CSCW '00: Proc. of the 2000 ACM conference on Computer supported cooperative work, pages 21–30, ACM, NY, USA (2000)
12. Maulsby, D., Greenberg, S., Mander, R.: Prototyping an intelligent agent through Wizard of Oz. Conference on Human Factors in Computing Systems (1993)
13. Gumienny, R., Böckmann, O., Willems, C., Quasthoff, M., Gericke, L., Meinel, C.: Verteiltes Design Thinking mit teleBoard. In Wandke, H., Kain, S., Struve, D., eds.: Mensch & Computer, pages 455–460, Oldenbourg (2009)
14. Rodden, T.: A survey of CSCW systems. Interacting with Computers **3**(3) (1991) 319–353
15. Kolko, J.: Information Architecture: Synthesis Technique for the Muddy Middle of the Design Process. In: 23rd International Conference on the Beginning Design Student Proceedings (2007)
16. Beyer, H., Holtzblatt, K.: Contextual Design: A Customer-Centered Approach to Systems Design. Morgan Kaufmann, CA (1997)