ICAT 2005
December 5-8, Christchurch, New Zealand

Coeno – Enhancing face-to-face collaboration

M. Haller[1], M. Billinghurst[2], J. Leithinger[1], D. Leitner[1], T. Seifried[1]
[1] Media Technology and Design / Digital Media Upper Austria University of Applied Sciences
[2] HIT Lab NZ, University of Canterbury
coeno@fh-hagenberg.at

Abstract

Augmented Surface Environments are becoming more and more popular and will change the mode of communication. Previous work has shown that projector based AR technology can be used to enhance face-to-face collaboration. We have implemented various interaction metaphors that have been integrated in an augmented tabletop setup. We describe our system in detail and present user feedback from people who have used the application. We also provide general design guidelines that could be useful for others who are developing similar face-to-face collaborative AR applications.

Key words: face-to-face collaboration, augmented surface environment, user study, tabletop setup

1. Introduction

Computers are increasingly being used to enhance collaboration. Distance communication via email and instant messaging is commonplace and higher bandwidth uses such as desktop video conferencing and voice over IP calling is growing in popularity. Despite this there has been less attention paid to using computers to improve face-to-face collaboration.

There is a vast body of literature relating to face-to-face conversation and collaboration. It is clear that people are capable of using speech, gesture, gaze and non-verbal cues to attempt to communicate in the clearest possible fashion. In many cases face-to-face collaboration is also enhanced by, or relies on, real objects or parts of the user's real environment [3].

For example in a brainstorming session or design review people typically collaborate around a table, and the space between then is used for sharing communication cues such as gaze, gesture and non-verbal behaviors. If the people are communicating about objects placed on the table then this task-space becomes a subset of the communication space [6].

However introducing a computer into the meeting may change the group dynamic. When users gather around a desktop or projection screen they are often sitting side by side and their attention is focused on the screen space (figure 1). In this case the task space is part of the screen space, and so may be separate from the interpersonal communication space. Thus collaborators may exhibit different communication behaviors with a screen-based interface than when seeing each other across a table.

Fig. 1 Separation of Task and Communication Space.

The focus of our research has been on developing computer interfaces that enhance face-to-face collaboration rather than negatively affecting it. Our prototype interface, Coeno, is an augmented surface environment that seamlessly supports the way people communication in a face-to-face meeting.

2. Related Work

Early attempts at computer support of face-to-face collaboration were based around conference rooms in which each of the participants had their own networked desktop computer. These computers were running distributed applications that allowed users to send text or data to each other. However, there were very few successful early computer conference rooms [10][13]. One of the reasons for this was the lack of a common workspace. User's collaborating on separate workstations, even if they are side-by-side, do not perform as well as if they were huddled around a single machine [7]. Indeed, researchers have found that when students are assigned to individual computers they will spontaneously cluster around machines in pairs and trios [20][21].

An early improvement was using a video projector to provide a public display space. A typical example was the Colab room at Xerox PARC [17] which had an electronic whiteboard that any participate could use to display information to others. The importance of a central display for supporting face-to-face meetings has been recognized by the developers of large interactive displays (such as the LiveBoard [5]). One of the more recent examples of a smart space for computer supported collaboration is the i-Land setup of Streitz et al. [19]. Their Roomware concept involves computer-augmented objects in a room that can be dynamically reconfigured to support face-to-face collaboration [12].

In unmediated face-to-face conversation, people are able to equally contribute to the collaboration. However observations of the use of large shared displays have found that simultaneous interaction rarely occurs due to the lack of software support and shared input devices [11]. It is difficult to have equal collaboration among co-located users when only one of the users has the input device to interact with the display. In recent years a class of groupware systems has arisen which support multiple input channels coupled to a single display. Stewart et al. coined the term Single Display Groupware (SDG) to describe this type of collaborative application [18]. They point out that some of the benefits of this approach include elimination of conflict among users for input devices, enabling more work to be done in parallel by reducing turn-taking, strengthening communication skills and encouraging peer-learning and peer-teaching.

Aside from multiple input devices, traditional interface metaphors can often not be used to interact with the data on large displays [4]. For example, pull down menus may no longer be accessible, keyboard input may be difficult and users may not want to share a single mouse input device [15]. A greater problem is that traditional desktop input devices do not allow people to use free-hand gesture or object-based interaction as they normally would in unmediated face-to-face collaboration.

In many interfaces there is a shared projected display visible by all participants; however, collaborative spaces can also support private data viewing. In Rekimoto's Augmented Surface's interface [14] users are able to bring laptop computers to a face-to-face meeting and drag data from their private desktops onto a table or wall display area. They use a new interaction technique called hyper-dragging which allows the projected display to become an extension of the user's personal desktop. Hyper-dragging allows users to see the information their partner is manipulating in the shared space, so hyper-dragging becomes an extension of the normal non-verbal gestures used in face-to-face collaboration.

3. Interface Requirements

In the previous section, we have presented a variety of interfaces designed to support face-to-face collaboration. From this work we can identify the following key interface requirements that a system should have:

- A common shared workspace
- Support for simultaneous input
- Public and private workspaces
- Support for gaze and non-verbal cues
- Appropriate interface metaphors
- Support for the use of real objects

In addition, in order for collaborative systems to move from the research environment to actual commercial use there are a number of other desirable features:

- A connection to the current existing software environment is essential (e.g. plug-in to Powerpoint, Word, Excel, etc).
- A connection to a media asset management system, including an easy-to-use interface for data access.
- The ability to capture a session history of the collaboration discussion.

These requirements were used as design guidelines for the Coeno application which we describe in more detail in the next section.

Robertson et al. identified six broad categories of large-display usability issues [15]. Based on their ideas, we believe that the following problem categories should also be addressed in our system:

- *Losing the Cursor:* By using multiple screens and different working spaces, participants easily lose the mouse cursor and it becomes harder to track it.
- *Distal information access:* By using different displays and projector based systems, the participants may have to interact over larger distances, which can become difficult and time consuming.
- *Task management:* The larger the display the more windows and data will be visualized. Thus, participants engage in a more complex multitasking behavior and the system has to support them with easy-data-handling.
- *Fast transfer of data:* Multi-display participants have to transfer data from one source to the other. An efficient interaction mechanism combined with fast data transfer makes the system more usable.
- *Multi-user access:* In a collaborative face-to-face setup, the handling of a fair access to the data for multiple users has to be guaranteed.
- *Orientation (Bezel problems):* Once people are sitting around the table, only one user has the best view to the public tabletop setup. However, all participants should have the same view to the data.
- *Configuration:* Current face-to-face applications have poor supported for the configuration of a heterogeneous hardware setup.

In our prototype interface, we focused primarily on the first five problems. In the next section we present some possible solutions. The orientation and configuration problems are left for further research.

4. Coeno

Coeno is a computer enhanced face-to-face presentation environment for discussions using tabletop technology in combination with digital information. It offers a cooperative and social experience by allowing multiple participants to interact easily around a shared workspace, while also having access to their own private information spaces and a public presentation space.

The first application area that we are focusing on is storyboarding. Designing a storyboard is a challenging task and demands a high level of collaboration between all participants. In most cases, people sit together around a table and discuss the different sequences of a new movie or animation. Unfortunately, only a few tools have been developed for making storyboard applications more interactive (such as [2]).

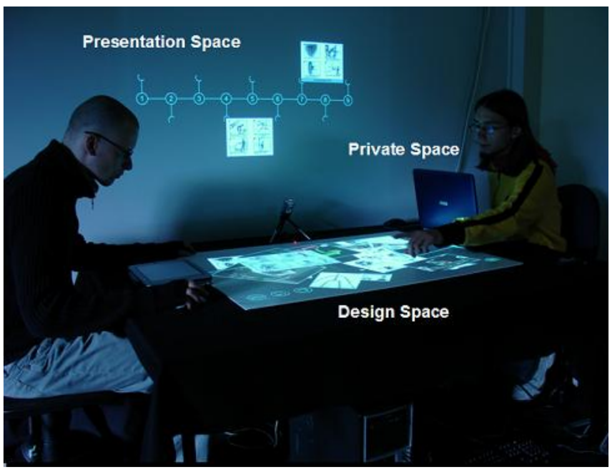

Fig 2: The Coeno interface with the different spaces.

The implementation of an easy-to-use interface for large-displays is a challenging task. The Coeno-Storyboard interface consists of a ceiling and a wall mounted projector showing data on a table surface and adjacent wall. These projectors are connected to a single display computer. Users can sit at the table and bring their own laptop or tablet PC computers that can be wireless connected to the display server. So there are three display spaces (figure 2):

Private Space: The user's laptop screen.

Design Space: The shared table surface, only visible to those sitting around the table.

Presentation Space: The wall projected display, visible to all the people in the room.

There is no limit to how many clients can connect simultaneously to the Coeno system, thus the amount of participants depends on the space around the table.

In the Storyboard application users can create imagery (e.g. scenario sequences, scribbles, 3d content) on their own personal computers (Private Space), move them to the Design Space for discussion, and then to the Presentation Space for final organization. The research challenge is to design interaction techniques so that these three spaces are seamlessly connected and that interacting with the data does not prevent normal face-to-face collaboration.

To move images from the private workspace to the shared design space we use the hyper-dragging metaphor of Rekimoto [14]. Users can click on an image on the desktop and drag it. Once the mouse reaches the edge of the physical desktop, the image appears on the table connected by a virtual line to the centre of the desktop. Dragging with the mouse continues to move the image across the table top (see figure 3). Participants are allowed to create new content only in their private space and then they can move them to the public space.

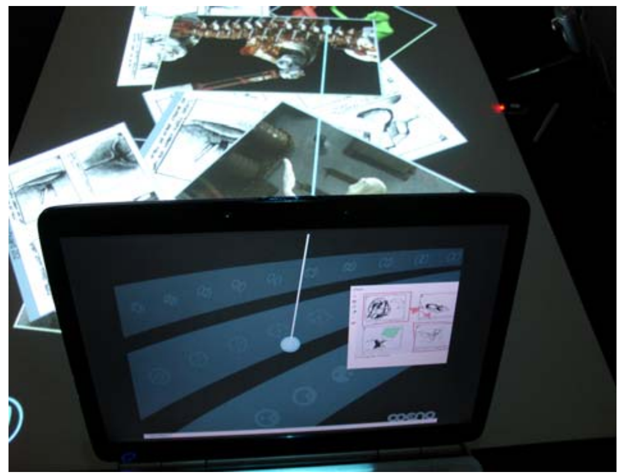

Fig. 3: Hyper-dragging from the desktop to tabletop.

The Design Space is a shared collaborative space, so that several people can be hyper-dragging the content on the table at the same time. In order to modify an image the user can drag their virtual mouse line out into the design space, click and select and image and drag it back onto their desktop. Once there, they can modify the image with normal desktop applications, before copying it back out into the shared workspace.

During discussion, all participants around the table can quickly re-arrange the storyboard images. Images on the table, can be moved, rotated, and scaled respectively. Once they have decided that an image should go in a particular order in the storyboard presentation, they can move it to the Presentation Space and arrange it on a presentation timeline.

There are two ways to move images between the table and wall projection spaces. First, one of the users assumes the role of coordinator and uses a wireless mouse to click on images on the table space and drag them up the table and onto the wall. In this way the wall display appears as a seamless extension of the table space. The second possibility is to double-click the image with the wireless mouse pointer. Consequently, a virtual keypad (cf. figure 4) is projected onto the table and when the user touches a number on the keypad the image will fly to the corresponding numbered position on the timeline.

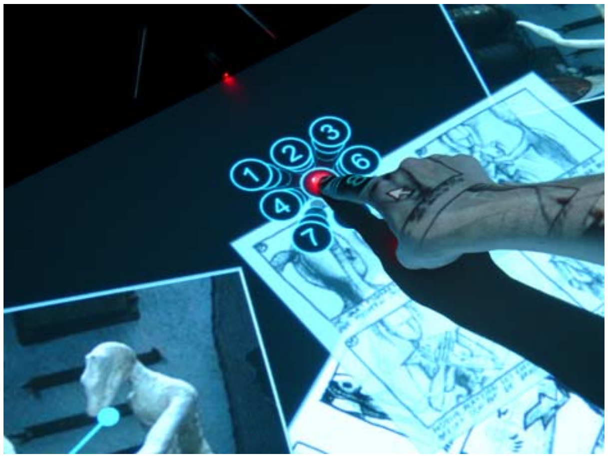

Fig. 4: Laser based touch input.

The projected keypad is an example of support for natural gesture input on the table surface. We currently achieve this through the use of a red laser diode that emits a thin laser line across the table surface. A camera that is mounted at the back of the table can be used to detect the reflection of the laser from user's fingers and support touch input. The usage of a red laser line guarantees that the tracking system works also under bad lighting conditions. In contrast to the commercially available virtual keyboards, we can change the projected layout relatively quickly by simply configuring a corresponding XML-file. Due to the fact that we track reflected light sources, we also can use a simple red laser pointer targeting to the surface instead of typing with the fingers.

Fig. 5: The virtual keyboard from i.Tech and the virtual augmented control elements can be used respectively.

In addition to the projected number pad, we also support input from commercially available projected keyboards (figure 5). We use a keyboard from [8] that uses a laser diode to project virtual keys on the tabletop and does simple depth sensing to recognize the key being touch. The keyboard then uses Bluetooth to wirelessly communicate the key presses back to the server computer.

The hyper-dragging metaphor, as originally presented by Rekimoto, has a problem, because the users often lose the mouse cursor. When there are several users selecting objects on the table then they may be unsure which virtual cursor is theirs. To address this problem, we added a visual extension cursor, a radar-mouse-cursor that shows inside the private space the position of the actual cursor on the table (figure 3). This appears as a line on the private screen space that connects with the projected virtual mouse line on the display space.

Due to the large display surface, there is a lot of data that can be shown at the same time. An intuitive method for complex handling, organization and visualization of data is required. We implemented the AppleExposé metaphor [1] for an efficient organization and management of the data on the table. With this technique when the user hits a single key all of the images in the Design Space are dynamically reorganized into an orderly row of tiles (figure 6). This allows for easy and fast document handling and reduces visual clutter.

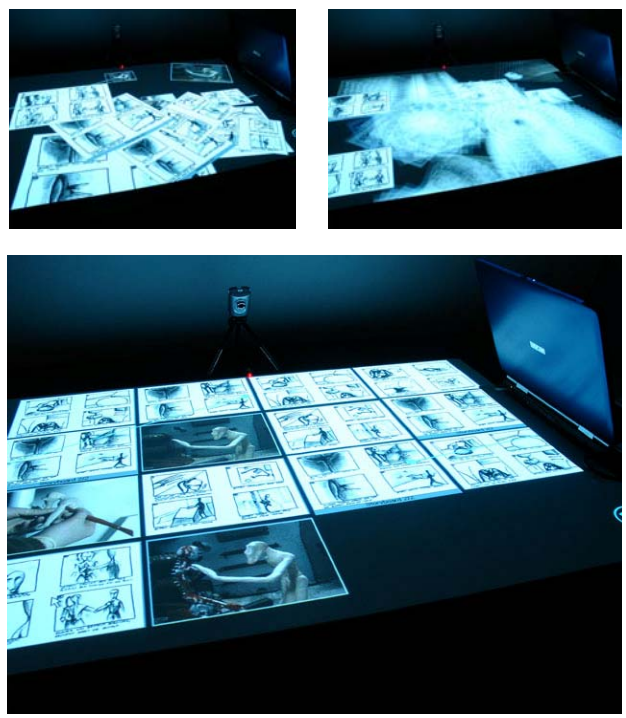

Fig. 6. Organizing the data.

During an editing session changes can be saved by using clicking with the wireless mouse on an icon on the desktop. Similar to Klemmer et al. [9], we used small thumbnails that represented visually a snapshot of the saved discussion session (figure 9).

5. User Feedback

In order to evaluate the usability of the Coeno interface, we conducted a small pilot user study. This was designed to encourage collaboration between three people focused on the same task. In this case, the task was to use the Coeno interface to present and discuss 28 different draft logo images and decide which three logos were the best.

The experiment was designed for three collaborators in two roles. Two of the collaborators were given the role of designers and sat at a laptop and tablet PC on either side of the Coeno table. On their computers were 14 draft logos each. They were to choose five images from the fourteen that they had and hyper-drag them from their desktop onto the shared table display. They could add annotations to logos using the text or drawing tools.

The third participant was given the role of moderator and his or her role was to help the designers work together to select three images from the ten on the table projection. The moderator had control of the wireless mouse and so could move images from the design surface to the presentation surface using the mouse or virtual keyboard. They could also arrange the logo drafts to get an overview or save and load sessions.

Before they begun the experiment subjects were given an overview of the Coeno interface and a demonstration of how the various interface elements worked. They were given the opportunity to practice with the hyper-dragging tool, wireless mouse and virtual keyboard until they felt comfortable with the interface.

Subjects were given as much time as needed to complete the task and when they were finished they filled out a subjective survey about how they felt about the interface and process of collaboration. They were also interviewed by the experimenter to explore some of their survey responses in greater depth.

5.1 Overall Results

Four groups of three subjects took part in the pilot study.

Fig. 7: Subjects in the user study.

The users were all students and staff who had considerable experience using computer interfaces, although most had not used a wireless presentation tool before. They were all able to complete the task taking 40 minutes each on average. Figure 7 shows one of the subject groups being observed by an experimenter, while figure 8 shows the icons being arranged on the desktop for discussion.

After each set of subjects were finished, a survey was presented to the subjects with a number of statements and they were asked how much they agreed or disagreed with the statement on a scale of 1 to 5 (1 = totally agree, 5 = totally disagree). Subjects were also asked for general comments and feedback about the experience.

In general the subjects were very satisfied with the communication between the group and felt that the hardware aided the discussion. When asked "I was satisfied with the communication between the users" the average over all response was 1.58 (SD 0.67) out of 5.0, and to the question "I think the hardware set up did assist the discussion" the average over all response was 2.0 (SD 0.85). In the interview sessions subjects mentioned how they enjoyed the simultaneous interaction of all users, the ease of use of hyper-dragging and the intuitiveness of the interface in general.

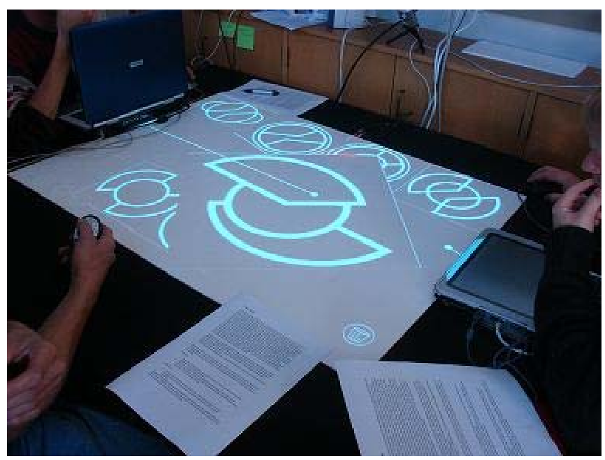

Fig. 8: Icons being viewed in the user study.

Data Exchange and Data Manipulation

Participants found that the movement of data from their private space to the Design Space was intuitive (1.75 average (SD 0.75)) and most of them found that the hyper-dragging metaphor was the right method for data exchange (1.27 average (SD 0.47)). However, they felt that it was too time-consuming and not accurate enough, but to our surprise they did not find it too tiresome after working a while. Most participants were still convinced that shortcuts or buttons projected on the table would help a lot to make data transfer faster. They felt that this was especially true if several objects had to be transferred at the same time. Only one person was convinced that hyper-dragging would be enough for data communication. In addition to the hyper-dragging method, they wanted to send data directly to each participant without having to move data firstly to the Design Space and from there to the desired participant. Half of the subjects wanted to have a direct communication way to another participant.

When asked “Was the transformation of the drafts on the table intuitive” the average over all responses was 1.75 (SD 0.87). In our setup, users manipulated the images with the wireless presenter and the mouse attached to their own devices. However, they mentioned that it would help a lot to have a more intuitive interaction metaphor for data manipulation on the Design Space. They felt that object rotation should not only be done by mouse, but also by a more intuitive hand gesture. Each of the groups wanted to manipulate not just one object, but a set of objects at the same time, for example, scaling a set of images and not just each of the images individually. The moderators all felt that the mouse speed was too slow.

An interesting feature mentioned by one of the groups is the usage of different colors for each of the participants. If each user has his/her own color for their virtual mouse line, it would be easier to find out the different interactions they were performing. This would help people looking at the Design Space to clearly identify with user was controlling which input line.

In most cases, moderators dragged data from the Design Table to the Presentation Wall. Interestingly enough, the virtual keyboard has not often used. When asked “Was the virtual keyboard useful?”, the average over all responses was only 2.75 (SD 1.26) out of 5.0. This may have been because it was difficult to reach across the table to touch the keypad image. Participants also wanted to get more support for direct interaction on the design table. Currently once they move image data to the table only the moderator could do more than drag the images around.

Even though, most subjects’ background was in 3D animation it was essential for them to get visualized images, before 3d models, text, video clips, PDF documents, and PowerPoint slides. Some of them also mentioned that it would be helpful to “visualize” sound files on the table.

Using different devices

Of the two subjects who were in the designer role, one used a laptop computer and the other a tablet PC. Although none of the users used a tablet PC before, 5 of 8 designers preferred working with the tablet PC instead of using the laptop. One of the reasons for this was that the tablet PC did not block the view of the design space unlike the laptop screen.

Most moderators thought that the use of multiple pointing devices (laser pointer and mouse cursor) was confusing. Thus, the laser pointer has rarely been used by the moderator. Instead, most of the moderators preferred the mouse courser for pointing to some data.

When asked if they knew where the mouse was, most subjects always knew where the mouse cursor was on their own screen (1.625 average (SD 0.74)), but had a lot of difficulties tracking the mouse cursor on the table surface (2.5 average (SD 1.17)). This shows that the mouse-radar-display was not as effective as it could have been.

A lot of participants liked the idea of having different work spaces that allowed them to concentrating on different tasks. They were also surveyed as to who should have the right to manipulate and modify their data. The moderators felt that only they should have the right to load and save data and move images to the presentation display. Half of the designers also felt that every user should have the ability to load images to the presentation all, and almost all (7 from 8) felt that everyone should be able to copy images to others private displays. The designers were equally split as to whether they would like their private screen viewed by others around the table or not. Thus most of the users wanted to have a liberal data sharing philosophy.

Coeno tools

Most subjects manipulated the content by adding graphic annotations using the tools on their laptop or tablet PC (1.71 average (SD 0.49)), however they were convinced that it would be more useful to modify the images directly on the table and not using their device (an average over all responses was 2.5 (SD 1.0) that they did not like to use their own device). Apart from the drawing and text tools, the tool most requested by users was a tool for cropping images (by 5 out of 8 users).

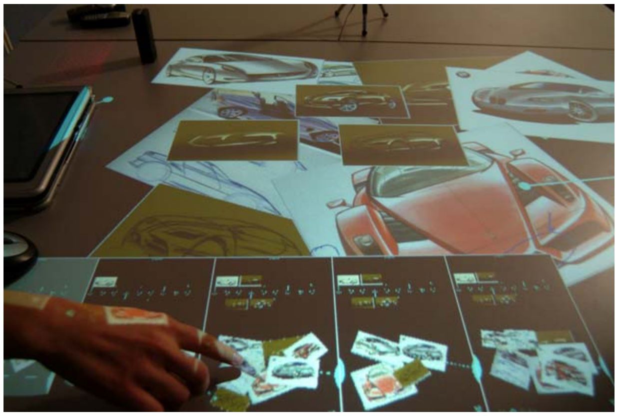

Fig. 9: Session snapshots are represented by small thumbnails.

The ability to capture a session history of the collaboration discussion was rated as extremely important by all moderators (1.0 average). The AppleExposé function was also seen as useful by all participants (1.75 average (SD 0.96)) and they did not want to miss it.

Summary

From this pilot study, we observed that the Coeno supports a stronger design collaboration than is provided by a traditional 2D graphical user interface, where all the participants sit isolated in front of a desktop PC. Thus, users seem to feel a stronger sense of identification with the story they are working on, because they can simply concentrate on the story instead of being distracted by the hardware.

A lot of the users were surprised by how natural the discussion was. They loved moving data notes from one client to the table and vice-versa and even with a huge amount of images on the working desk, they never felt lost. Once the images were moved to the table, some of the participants started to point at them using their hands with the expectation that they could move and transform the notes accordingly.

Even though the users felt the interface was very useful, we are in an early stage of the project, and we recognize that there are a number of ways to improve the current application. For example, when several people gather around the table, there is no single directional viewing angle that is ideal for every participant. To overcome this, the system should guarantee a flexible and fast movement of data sources around the table.

6. Design Recommendations

From the pilot study results and by observing the subjects using the system, we can make a number of design recommendations that could be applied to future Coeno applications and other similar systems for supporting face-to-face collaboration.

First, it is important that users can clearly identify who is manipulating each data object. In the current application each user had their own virtual mouse line pointer. In future applications these should all be uniquely colored so that it is obvious who is interacting with the data.

A common workspace facilitates face-to-face collaboration and it is important to place interaction tools in the design space. Although designer users could move images into the workspace, they could not perform more complex interactions on them once they were there, such as annotations, scaling etc. Many users tried to manipulate the objects in front of them with their hand gestures even though this was not supported.

However, in order to reduce visual clutter in the design space control elements should be projected on demand (e.g. virtual keyboard, control buttons etc.). Thereby, the whole working space is clean and people can focus on the content they are discussing.

In a face to face setting content control can be let to mainly social norms. The users in the pilot study did not feel a need to explicitly lock modification control over data objects because they were present and could see who was attempting to modify the objects.

The connection between public and private viewing spaces should be seamless and awareness tools should be provided so that when users are focusing on their private viewing space they can still be aware of what is happening in the public space. In the current application users sometimes found it difficult to see beyond their laptop screen to see into the design space.

Gaze and non-verbal cues are important and the interaction metaphors implemented should support them. In our case, users could easily see their collaborators and the object they were pointing to. In the future gesture based interaction methods should be added so that user input could also provide some additional gesture cues.

7. Conclusions and Future Work

In this paper, we have presented Coeno-Storyboard, a face-to-face presentation program for storyboards using tabletop technology in combination with augmented, digital information.

The main contributions of this paper were the following:

- *Design, implementation, and combination* of different interaction techniques for a face-to-face collaboration using projector based AR technology.

- *A pilot user study* to evaluate the implemented results: during our user study, we recognized that a lot of the participants wanted to get results in a very short time and they did not want to spend too much time for the setup training. Therefore, the system should be easy-to-use and the implemented metaphors should be neither too time-consuming nor too tiresome.

- Finally, we presented some *design recommendations* for similar systems for supporting face-to-face collaboration.

In Coeno, all data can be transformed by each of the participants. Actually, we do not support a layout management system that supports data visualization that guarantees the optimal viewing angle that is ideal for every participant (as proposed by Ryall et al. [16]). However, we think that this is a really important feature. It is doubtful that all participants have to see *all* data from their view at the same time, but at least the most important information should be presented in optimal conditions for all users.

Currently, we are working on a connection to a media asset management system in combination with a speech recognition interface. Thus, we want to offer an intuitive user interface for more powerful queries.

Acknowledgements

We would like to acknowledge the work of Adam Gokcezade, Christina Koeffel, and Johannes Kehrer on earlier versions of the COENO at the Upper Austria University of Applied Sciences. The project was partially funded by voestalpine Informationstechnologie and by the Oesterreichische Forschungsförderungs-gesellschaft mbH (FFG) as part of the FHplus program.

References

[1] www.apple.com/macosx/features/expose/

[2] Brian Bailey, Interactive sketching of multimedia storyboards, In MULTIMEDIA '99: Proceedings of the seventh ACM international conference on Multimedia (Part 2) pp. 205-206, 1999

[3] Mark Billinghurst and Hirokazu Kato, Collaborative augmented reality, Communications of the ACM, vol. 45, n. 7, 2002, pp. 64-70

[4] Xiang Cao, Ravin Balakrishnan. (2004). VisionWand: Interaction techniques for large displays using a passive wand tracked in 3D. ACM Transactions on Graphics, 23(3). Proceedings of SIGGRAPH 2004. p. 729.

[5] Elrod, S., Pier, K., Tang, J., Welch, B., Gold, R., Goldber, d., Halasz, F., Janssen, W., Lee, D., McCall, K., Pedersen, E. Liveboard: A large interactive display supporting group meetings, presentations and remote collaboration. In the proceedings of *CHI'92*, pp. 599-607, May 1992.

[6] K. O'Hara, M. Perry, E. Churchill, D. Russell (Ed.): Public and Situated Displays: Social and Interactional Aspects of Shared Display Technologies, Kluwer Publishers, 2003. pp. 387-409

[7] Inkpen, K. Adapting the Human Computer Interface to Support Collaborative Learning Environments for Children. PhD Dissertation, Dept. of Computer Science, University of British Columbia, 1997.

[8] http://www.itechdynamic.com/

[9] Scott R. Klemmer, Mark W. Newman, Ryan Farrell, Mark Bilezikjian, James A. Landay, The Designers' Outpost: A Tangible Interface for Collaborative Web Site Design. UIST 2001: ACM Symposium on User Interface Software and Technology, CHI Letters, 3(2): pp. 1–10.

[10] Kraemer, K., King, J. Computer Supported Conference Rooms: Final Report of a State of the Art Study. Dept. of Information and Computer Science. Univ of California, Irvine, Dec 1983.

[11] Pedersen, E.R., McCall, K., Moran, T.P., Halasz, F.G. (1993). Tivoli: An Electronic Whiteboard for Informal Workgroup Meetings. In Proceedings of Human Factors in Computing Systems (InterCHI 93) ACM Press, pp. 391-398.

[12] Th. Prante, N. A. Streitz, P. Tandler, Roomware: Computers Disappear and Interaction Evolves. In: IEEE Computer, December, 2004. pp. 47-54.

[13] Ramesh Raskar, Greg Welch, Matt Cutts, Adam Lake, Lev Stesin and Henry Fuchs, (1998): The Office of the Future: A Unified Approach to Image-Based Modeling and Spatially Immersive Displays, ACM SIGGRAPH 1998, Orlando FL.

[14] Rekimoto Jun, Saitoh Masanori (1999), Augmented surfaces: a spatially continuous work space for hybrid computing environments, In CHI '99: Proceedings of the SIGCHI conference on Human factors in computing systems, 1999.

[15] Robertson, G., Czerwinski, M., Baudisch, P., Meyers, B., Robbins, D., Smith, G., Tan, D. Large Display User Experience. In IEEE Computer Graphics & Application, Special Issue on Large Displays, July/August 2005, pp. 44-51.

[16] Ryall, K.; Forlines, C.; Shen, C.; Ringel-Morris, M., "Exploring the Effects of Group Size and Table Size on Interactions with Tabletop Shared-Display Groupware", ACM Conference on Computer Supported Cooperative Work (CSCW), ISBN: 1-58113-810-5, pp. 284-293, November 2004 (ACM Press)

[17] Stefik, M., Foster, G., Bobrow, D., Kahn, K., Lanning, S., Suchman, L. Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings. In Communications of the ACM, January 1987, Vol 30, no. 1, pp. 32-47.

[18] Stewart, J., Bederson, B., Druin, A. (1999) Single Display Groupware: A Model for Co-Present Collaboration. In Proceedings of Human Factors in Computing Systems (CHI 99), Pittsburgh, PA, USA, ACM Press, pp. 286-293.

[19] N.A. Streitz, Th. Prante, C. Röcker, D. van Alphen, C. Magerkurth, R. Stenzel, D. A. Plewe Ambient Displays and Mobile Devices for the Creation of Social Architectural Spaces: Supporting informal communication and social awareness in organizations.

[20] Strommen, E.F. (1993) "Does yours eat leaves?" Cooperative learning in an educational software task. Journal of Computing in Childhood Education, 4(1), 45-56.

[21] Watson, J. (1991) Cooperative learning and computers: One way to address student differences. The Computing Teacher, 18(4), p. 9-15.