Toward Seamless Collaboration Media: From TeamWorkStation To ClearBoard [1]

Hiroshi Ishii [2]

Abstract

Collaboration is a promising application domain of multimedia networks. This paper presents an evolution of our collaboration media design from TeamWorkStation to ClearBoard. The key concept of our media design is "seamlessness". TeamWorkStation provides distributed users with a seamless shared workspace. Users can continue to use favorite application programs or desktop tools, so there is only a minor cognitive seam between individual and shared workspaces. To integrate the shared workspace and the partner's image seamlessly, we designed ClearBoard. Based on a metaphor of transparent glass board, ClearBoard permits co-workers in two different locations to draw with color markers or electronic pen while maintaining direct eye contact and the use of natural gestures.

I. Introduction

"Computer-Supported Cooperative Work (CSCW)" emerged in the middle of the 80s as an identifiable research field focused on the role of computer technology in group work. CSCW examines how people work together in groups and how technologies can support them. We have been studying how computer and realtime video communication technologies can support people working together in groups over distance. We have designed a variety of collaboration media. "Seamlessness" has been a key concept of our evolving media design.

Ideally, tools enable us to work smoothly and without interruption. Complex computer-based tools, however, often require our attention, distracting us temporarily from the work we are doing. "Seamlessness" in the sense of eliminating unnecessary, obstructing, perceptual seams has been a key concept of our evolving media design. Collaborative work is particularly marked by spatial, temporal, and functional constraints that force us to shift among a variety of spaces or modes of operation. Seamless design undertakes to decrease the cognitive loads of users as they move dynamically across different aspects of their work.

Figure 1 is an idealized trajectory of our research. This paper illustrates the progression of iterative design from TeamWorkStation-1 and TeamWorkStation-2 to ClearBoard-1 and ClearBoard-2.

II. TeamWorkStation-1 and Seamless Shared Workspace

People develop their own work practices after using a wide variety of manual and computer tools. Groupware can only be accepted if it supports continuity with existing individual work environments. Seamlessness is the key issue because users frequently move back and forth between individual and collaborative modes. We designed TeamWorkStation (TWS) to realize a "seamless shared workspace" that allows users to keep using their favorite computer and manual tools for group work.

The key design idea of TWS is a "translucent overlay" of individual workspace images. TeamWorkStation combines two or more translucent live-video images of computer screens or physical desktop surfaces by using a video synthesis technique. Translucent overlay allows users to combine individual workspaces and to point to and draw on the overlaid images simultaneously.

The first prototype, TWS-1 was implemented in 1989 [1][2]. Fig. 2 shows an overview of the prototype. Two CCD video cameras are provided at each workstation: one for capturing live face images of the member, and the other for capturing the desktop surface images and hand gestures. TWS-1 provides two screens. The individual screen is on the left and the shared screen is on the right. These two screens are contiguous in video memory.

This multi-screen architecture allows users to move any application program window between the individual and shared screens just by mouse dragging. Therefore, it is easy to bring your own data and tools from each personal computer into the shared workspace to use in remote collaboration. Hardcopy information can also be shared easily by placing it under the CCD camera. Fig. 3 shows an image of a shared screen. Two users are discussing the system configuration by annotating diagrams in a draw editor by hand.

TWS-1 is designed to provide small work groups (2-4 members) with a shared workspace, and live video and audio communication links for face-to-face conversation. The first prototype TWS-1 is based on Macintosh™ computers. The system

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1 This paper describes the progress of "Seamless Media Design" project at NTT Human Interface Labs. Descriptions of TeamWorkStation from [4] and ClearBoard from [6] are incorporated in this article with the permission of ACM.

2 Dr. Ishii is working at the University of Toronto and NTT Human Interface Labs. He may be reached at ishii.chi@xerox.com.

architecture of the TWS-1 is illustrated in Fig. 4. In order to connect distributed workstations, a video network (NTSC and RGB) and an input device network were developed and integrated with existing data network (LocalTalk™ network) and voice (telephone) network. We are now integrating these four networks into a multimedia LAN and B-ISDN.

The video network is controlled by a video server that is based on a computer-controllable video switcher and video effecter. The video server gathers, processes and distributes the shared computer screen images, desktop images, and face images. Overlay of video images is done by the video server. The results of overlaying are redistributed to the shared screens via the video network.

TWS provides a "seamless shared workspace" in which participants can freely use a variety of everyday media, such as computer tools, hand writing, printed materials, and hand gestures simultaneously. Through many experiments, we realized that TeamWorkStation achieves "cognitive seamlessness" by allowing users to keep using their favorite individual tools while collaborating in a shared workspace [4].

One problem of the overlay approach is that the results of collaboration can not be shared directly. We mainly used a video printer or video tape recorder to record the results and the collaboration process.

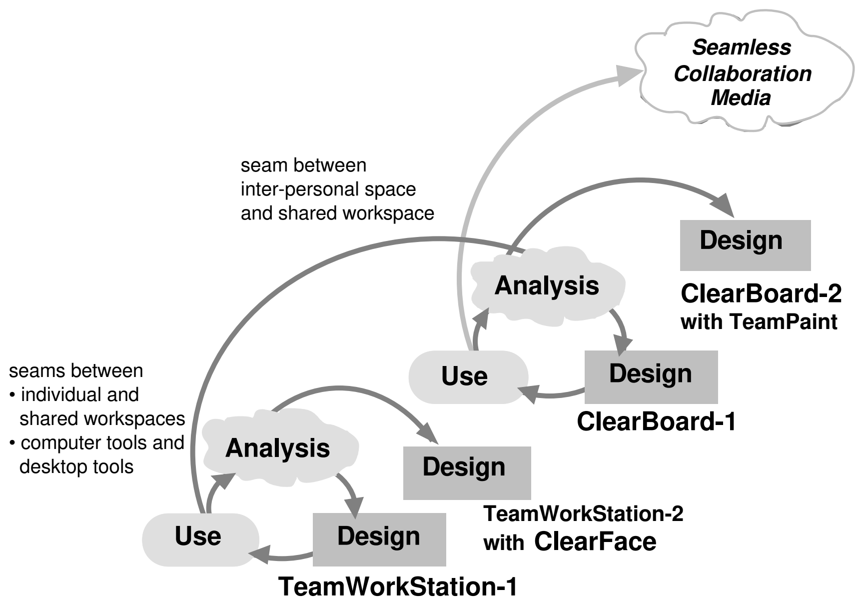

Fig. 1 Trajectory of Our Collaboration Media Design

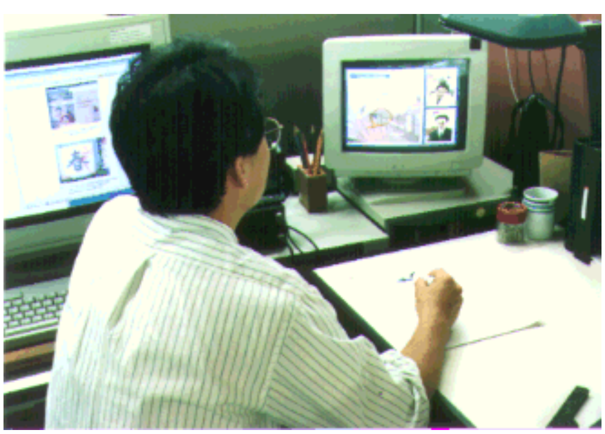

Fig. 2 Overview of TeamWorkStation-1 Prototype

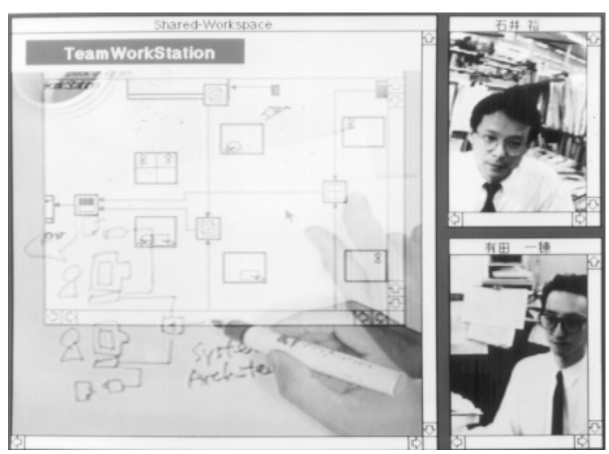

Fig. 3 A Shared Screen of TeamWorkStation-1

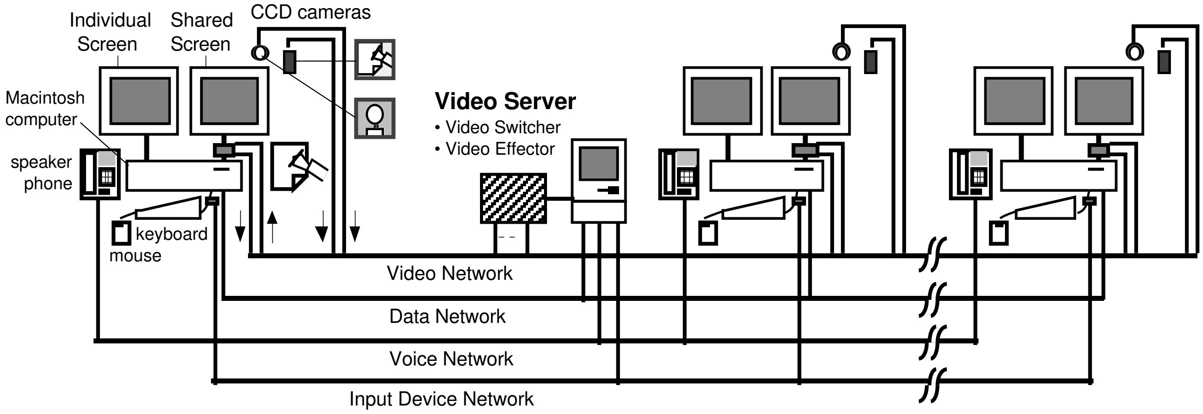

Fig. 4 System Architecture of TeamWorkStation-1 Prototype [4]

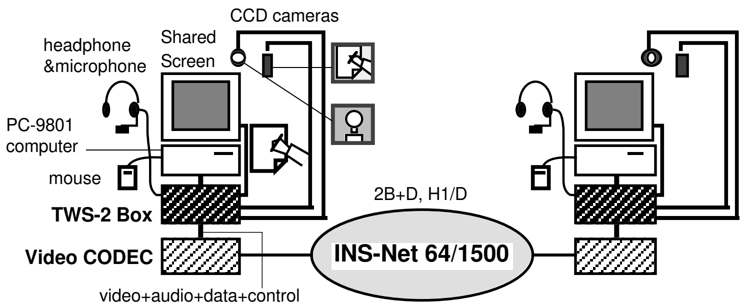

Fig. 5 System Architecture of TeamWorkStation-2 Prototype [7]

III. TeamWorkStation-2 with New Multiuser Interface: ClearFace

TeamWorkStation-2 (TWS-2) was designed for Narrowband ISDN (INS-Net 64 and 1500 in Japan) in 1992. The system configuration and user interface were simplified based on feedback from test users in NTT. Fig. 5 shows the system architecture of the TWS-2 prototype. We have introduced a new multiuser-interface technique called "ClearFace" [3]. ClearFace is the "translucent live face images over the shared workspace" (see Fig. 6). The serious weakness of the original TeamWorkStation was the restricted shared screen space. To solve this problem we devised "ClearFace". In ClearFace, the entire screen can be used as a shared workspace.

Experiments confirmed that users have little difficulty in visually separating the drawing layer objects from the translucent face layer. This is explained by the theory of "selective looking".

Since users sometimes want to see the partner's face clearly rather than seeing both face and the drawing image behind it, TWS-2 allows the user to easily switch the face images from translucent to opaque.

Another interesting observation is that all subjects hesitated to draw over faces. When they drew figures or wrote text on the shared drawing space, they tried to avoid colliding with face images. We countered this behavior by allowing each user to freely drag the face images around.

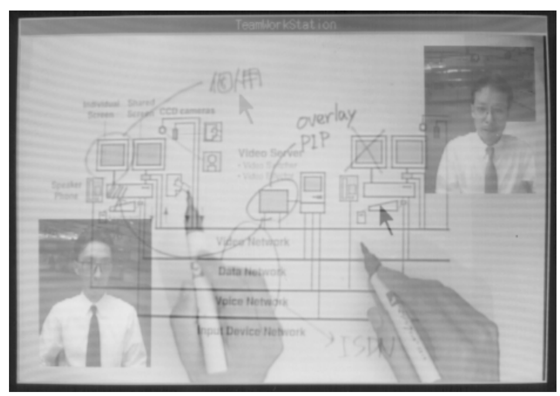

Fig. 6 TeamWorkStation-2 with ClearFace

Remote Instruction of Calligraphy

Fig. 7 shows a calligraphy teaching session with TWS-2. The student draws Chinese characters on his desktop using a brush with black ink. The instructor watches the student's realtime strokes via the shared screen and makes necessary comments by using a brush with red ink on the paper on his desktop. The instructor can make his comments directly over student's strokes when the student deviates from the suggested forms, and the student gains the immediate feedback of the teacher. Through these calligraphy experiments, we realized that the most important feature is that all the collaborators share not only the results of drawing, but also the dynamic process of drawing and pointing [4].

Fig. 7 Calligraphy Teaching using TWS-2

IV. ClearBoard

In a face-to-face design meeting using a whiteboard, we frequently switch our attention between the partner's face and the drawing surface. Even when drawing, we often briefly glance at our partner's face to attract attention or to gauge comprehension. This dynamic and interactive focus switching between drawing surface and partner's face is triggered by a variety of non-verbal cues such as eye contact, eye movement, head turning, and gestures.

Current groupware technologies do not support these cues. Users cannot switch their attention between the two spaces smoothly and naturally. In existing desktop video-conference systems such as TeamWorkStation, the images of participants and the shared workspace are displayed in spatially separated windows. There is an arbitrary seam between the windows, and the seam prevents smooth and natural transition.

Lack of eye contact is another problem of TeamWorkStation. People feel it difficult to communicate when they cannot tell if the partner is looking at them. Some users complained about the "indirect-drawing and pointing" on the desktop by hand. This problem motivated us to develop a "direct-drawing" solution.

ClearBoard is designed to create a shared drawing medium for pairs of users that overcomes these limitations and seamlessly bridges interpersonal space and shared workspace [6]. ClearBoard allows users to shift easily between these spaces by using familiar everyday cues such as the partner's gestures, head movements, eye contact, and gaze direction (see Fig. 10).

ClearBoard Metaphor

In order to integrate shared workspace and interpersonal space seamlessly, we devised the new metaphor of "talking through and drawing on a big transparent glass window." We named it "ClearBoard" [5]. Fig. 8 illustrates this concept of ClearBoard.

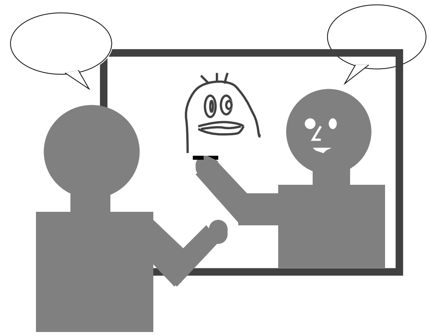

Fig. 8 ClearBoard Metaphor: Talking through and Drawing on a Transparent Glass Window

In ClearBoard, since the partner's face and drawings are closely located on the board, refocusing between the drawing and the partner's face requires less eye movement. One problem of this metaphor is that participants have no common orientation of "right" and "left". However, this problem can be solved easily in implementing the remote version by mirror-reversing the video image.

V. Design of ClearBoard-1

Fig. 9 shows ClearBoard-1; our first prototype to support remote collaboration [5]. Two users are discussing a route by drawing a map directly on the screen surface. Both users can share a common map orientation. The partner can read all text and graphics in their correct orientation.

Fig. 9 ClearBoard-1 in Use

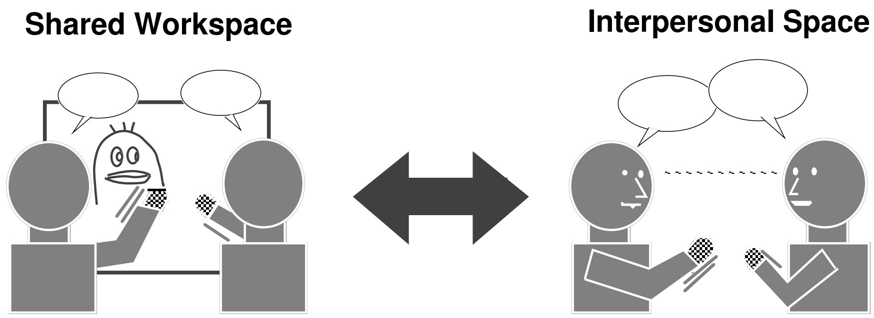

Fig. 10 Goal of ClearBoard Design: Seamless Integration of Shared Workspace and Interpersonal Space

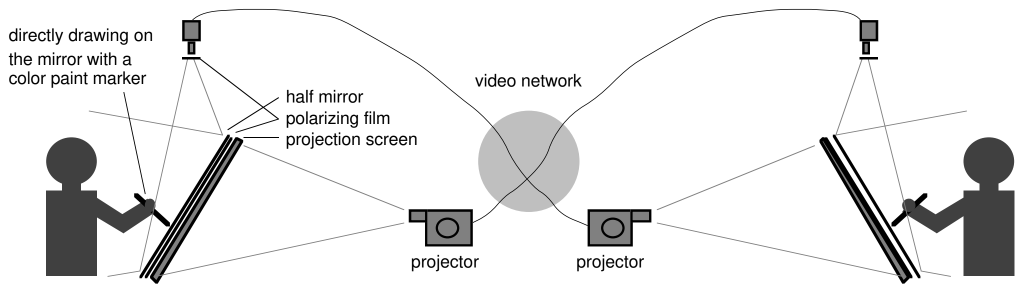

Fig. 11 Architecture of ClearBoard-1 prototype [6]

Architecture of ClearBoard-1

In order to implement the ClearBoard concept, we devised the new system architecture illustrated in Fig. 11. Each terminal is equipped with a tilted screen, a video projector and a video camera. Users can write and draw directly on the surface of the screen using color paint markers. The video camera located above the screen captures the drawings and the user's image as reflected by the half-mirror as a continuous video image. This image is sent to the other terminal through a video network and projected onto the partner's screen from the rear so that both users can share common orientation of the drawing space.

We implemented ClearBoard-1 at the end of 1990. Since then we have used this prototype in experimental sessions. We found that users can easily achieve eye-contact when needed. Easy eye contact even during drawing-intensive activities increased the feeling of intimacy and co-presence. Users had no trouble in distinguishing drawing marks from the video background. The transparent glass window metaphor seems to make users sensitive to the distance between the drawing and the partner.

Gaze Awareness

The most novel feature of ClearBoard and the most important, is that it provides precise "gaze awareness" or "gaze tracking." A ClearBoard user can easily recognize what the partner is gazing at on the screen during a conversation. Precise gaze awareness can not be achieved easily in an ordinary meeting environment using a whiteboard because both users stand on the same side of the board.

To understand the implication of gaze awareness, we conducted a collaborative problem solving experiment on ClearBoard using the "river crossing problem." This experiment confirmed that it is easy to say which side of the river the partner was gazing at, and this information was quite useful in passing advice to each other [5]. The importance of eye-contact in the design of face-to-face communication tools is often discussed. However, we believe the concept of gaze awareness is more generalized and is a more important notion. Eye contact can be seen as a special case of gaze awareness.

VI. Design of ClearBoard-2

In using this ClearBoard-1 prototype, we found several problems. The projected video image of drawing is not sufficiently clear. Erasing the marks is burdensome especially after the color paint has dried. Lack of recording capabilities is an obstacle to reusing the work results.

To overcome these problems in ClearBoard-1, we decided to design a new computer-based prototype, "ClearBoard-2" [6]. Instead of using color paint markers, ClearBoard-2 provides users with "TeamPaint", a multiuser computer-based paint editor and digitizer pen.

TeamPaint

TeamPaint is a groupware application that runs on networked Macintosh computers, and it is based on a replicated architecture. TeamPaint offers several functions: recording of working results, easy manipulation of marks, and the use of data held in computer files. TeamPaint provides an intuitive interface based on the metaphor of drawing on a sketch pad with a color pencil as shown in Fig. 12. To maximize transparency, it is a simple bit-map paint editor, not an object oriented draw editor.

Each user is provided with individual layers and can only modify his or her own layers by default. All members see the composite image of all the layers. Because each layer is isolated from the others, no access control is necessary. TeamPaint has no floor control mechanisms but enables simultaneous gesturing and drawing by multiple users.

Gestures, in the form of cursor movements, and through them the drawing process, are visually shared by all members. This feature is important in enhancing the sense of group dynamics in distributed activity.

Experimental Use of ClearBoard-2

Using TeamPaint, transparent digitizer sheets, and electronic pens, we implemented the computer-based prototype, ClearBoard-2 in early 1992. Fig. 13 shows the ClearBoard-2 prototype in use. The composite drawing image of TeamPaint is made to overlay the face images with a special video overlay board. The mixed RGB video image is projected onto the screen's rear surface. TeamPaint makes the human interface much more flexible and the drawing marks easier to see. The lower screen angle decreases arm fatigue, but the impression is that the partner is under the screen, rather than behind it as in ClearBoard-1.

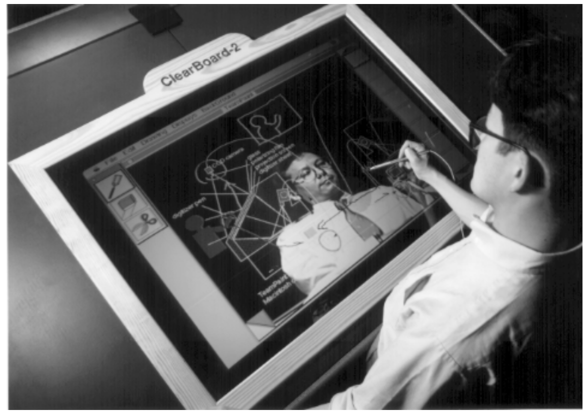

Fig. 13 ClearBoard-2 in Use

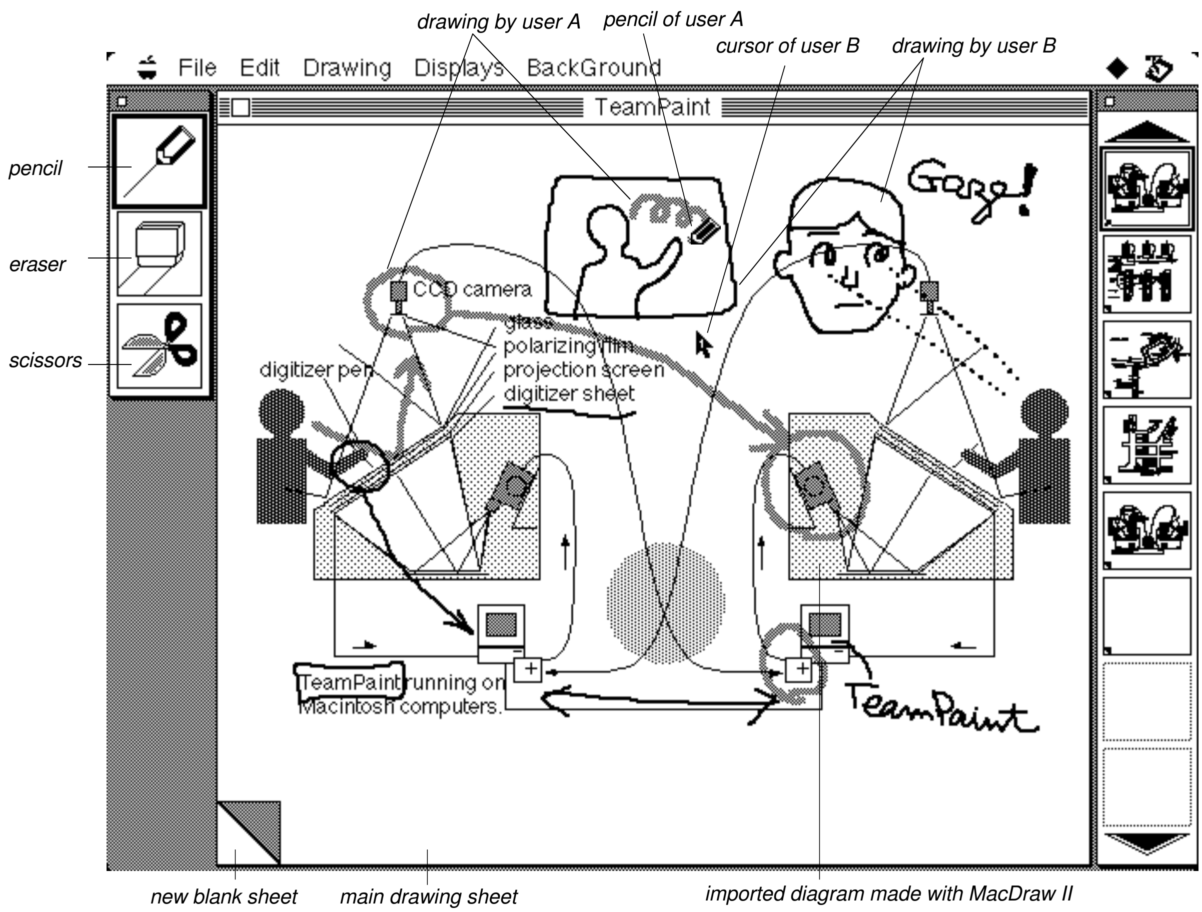

Fig. 12 A Screen of TeamPaint [6]

The use of RGB video and the chroma-keying overlay technique does increase image clarity. Furthermore, the capability of recording results and reusing the data produced in previous sessions or from any other application program promises to add tremendous value to an already practical tool.

Through the use of ClearBoard-2, it was often observed that the user's gaze follows the partner's pen movements. We confirmed that "gaze awareness" is as well supported as in ClearBoard-1. One can easily tell at which object in the TeamPaint screen the partner is looking.

ClearBoard-2 can be seen as a bridge between two different technology streams: groupware and videophones. We expect that the seamless integration of computer-based groupware technology and video communication technology will realize the next generation of collaboration media.

VII. Summary

We have presented an evolution of our collaboration media design from TeamWorkStation-1 to TeamWorkStation-2 to ClearBoard-1 to ClearBoard-2.

TeamWorkStation provides distributed users with a seamless shared workspace. Users can continue to use favorite application programs or desktop tools, so there is only a minor cognitive seam between individual and shared workspaces. Using this translucent video overlay technique, real-time information such as hand gestures and hand-written comments can be shared as well as information contained in printed materials and computer files. In order to solve the space problem in the shared screen, we devised a new multi-user interface technique, ClearFace, that is "translucent live face windows over shared workspace."

In order to integrate the shared workspace and the interpersonal space seamlessly, we designed ClearBoard. ClearBoard-1 permits co-workers in two different locations to draw with color markers while maintaining direct eye contact and the use of natural gestures. Through experiments, we found the new feature of "gaze awareness". In order to offer new functions, such as recording of working results, easy manipulation of marks, and the use of data held in computer files, we designed a computer-drawing version, ClearBoard-2. ClearBoard-2 supports shared drawing with TeamPaint and electronic pens.

The key concept of our media design is "seamlessness". We believe it is most important to respect the skills that people use in everyday life[3]. We have focused on skills such as talking, gesturing, gaze reading, drawing, and using computers. Based on these skills, our design will lead to cognitive seamlessness.

[3] The importance of skill-based design was originally proposed by Prof. William Buxton at the University of Toronto in the opening panel of ACM CHI '92.

Acknowledgments

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Author Information

Hiroshi Ishii received B. E. degree in electronic engineering, M. E. and Ph. D. degrees in computer engineering from Hokkaido University, Japan, in 1978, 1980 and 1992, respectively. He joined NTT Yokosuka Electrical Communications Laboratories in 1980. He is currently a senior research engineer, supervisor of NTT Human Interface Laboratories, Japan.

In 1986 and 1987, he was a visiting research associate at GMD (The German National Research Center for Computer Science) in Bonn, Germany. From June 1993 till May 1994, he is a visiting assistant professor at the University of Toronto, Canada

His research interests focus on human-computer interaction (HCI), Computer-Supported Cooperative Work (CSCW), and the role of CSCW technologies in cross-cultural communication. He has a number of publications including papers on TeamWorkStation published in Communications of the ACM in Dec. 1991 and a paper on ClearBoard to appear in ACM TOIS in Oct. 1993. He is currently an Associate Editor of ACM TOIS (Transactions on Information Systems), an Editor of Journal of Collaborative Computing, and an Advisory Board member of the International Journal of Computer Supported Cooperative Work. He also serves as a program committee member of many international conferences, including ACM CSCW '90, '92, ECSCW '91, '93, ACM CHI '90, 91, '92, '94, INTERCHI '93, ACM MULTIMEDIA '93, ACM COOCS '93, ACM ECHT '92. He is a member of ACM, Computer Society of IEEE, IPSJ, and IEICE Japan .