Encouraging Contribution to Shared Sketches in Brainstorming Meetings

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Figure 1. A collaborative sketching system allows group members in a design brainstorm to simultaneously work on the same sketch. Giving each member a Tablet PC to access the shared drawing space lowers the threshold for contribution.

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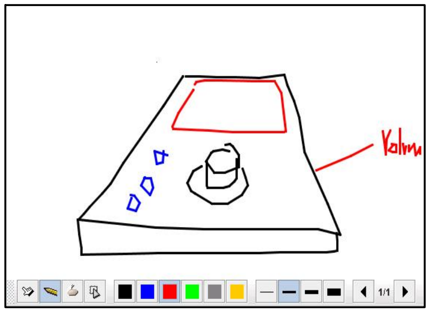
Abstract
Brainstorming in small design groups typically involves one person taking notes and sketching at a whiteboard while other group members remain seated and contribute verbally. We believe that lowering the threshold for shared sketching improves idea generation from all members and supports building off the ideas of other members. We have designed and completed preliminary testing of a collaborative sketching system that enables simultaneous contribution to and viewing of a shared canvas through individual devices (Tablet PCs) and a digital whiteboard. A pilot study indicates that such a system helps equalize sketching contribution within a group although it reduces total sketching of the group as a whole. This finding suggests that individual access to a shared sketching space has implications for the brainstorming process such as a greater awareness of the quality and the relative amount of individual idea contribution.

Keywords
Design meetings, brainstorming, sketching, Tablet PC, digital whiteboard, collaborative sketching.

ACM Classification Keywords
H.5.3: Group and Organization Interfaces: *Computer-supported cooperative work,* H.5.2: User Interfaces: *input devices and strategies; Interaction style*.



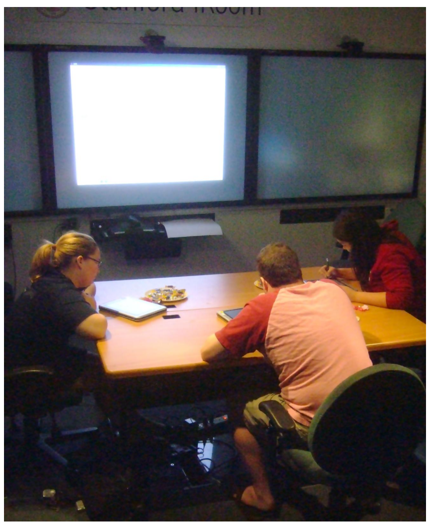


Figure 2. The collaborative sketching system affords simultaneous input to and viewing of a shared sketching space (top) through networked Tablet PCs and a digital whiteboard (bottom).

Introduction

Group brainstorming in small, collocated, synchronous meetings is an integral part of the design process. Typically during brainstorming, one group member acts as a "recorder" and takes notes on a whiteboard to support the group discussion. The other members sit oriented toward the whiteboard with individual logbooks for taking personal notes. The whiteboard plays an important role in mediating the group interaction by focusing attention on a large shared display. The sketching that occurs on the whiteboard is an important part of the brainstorming activity as research shows that sketching contributes to group communication and to the process of idea development and expression [5]. Sketching supports re-interpretive thinking cycles and access to earlier ideas [6].

The physical qualities of the tools and of the settings of current brainstorming meetings do not adequately support shared drawing by multiple people. Working simultaneously on the same sketch at the whiteboard is awkward because people must stand close together and often get in each other's way.It is physically impossible to work in the exact same location on the board. Research suggests a need for concurrent access to the drawing space in collaborative group meetings [5].

In addition, we observe that those seated during meetings are unlikely to stand up and approach the whiteboard. We believe this is due to the physical effort and time involved. In many cases, when a verbally expressed idea is not understood, seated members must be explicitly asked to go to the whiteboard and draw their idea. Thus, in brainstorming meetings, primarily one person writes to the whiteboard, which biases what gets recorded and how it is recorded.

Digital whiteboards bring benefits such as automatic documentation and display of external images to the traditional whiteboard interface. We believe that in current practice, the use of standalone digital whiteboards during meetings typically follows the interaction patterns of traditional whiteboards.

We have designed a collaborative sketching tool that allows multiple users to simultaneously contribute to the same canvas through individual devices and a digital whiteboard (see Fig. 2). The system includes Tablet PCs for each group member and a digital whiteboard for the group. The devices run a networked sketching application, allowing each group member to easily view and add to the same shared sketching space. We believe that equalizing access to view and contribute to the public space lowers the threshold for sketching and that collocated input and display further supports collaboration.

Related Work

Rekimoto investigated multiple device input to a digital whiteboard for supporting meetings [4]. His initial goal was to address user interface issues of earlier digital whiteboards by distributing some of the whiteboard functions to Personal Digital Assistants (PDAs). Rekimoto's work evidenced the benefit of digitally augmented whiteboards (facilitating content manipulation and layout). His system is similar to ours as both use multiple input devices to a digital whiteboard. However, the PDAs in Rekimoto's system function as "an artist's palette" to the whiteboard canvas while we intend for the Tablet PCs in our system to be used as mirrors of the whiteboard itself. Rekimoto emphasizes physically approaching the whiteboard to transfer content to the shared space through the Pick-

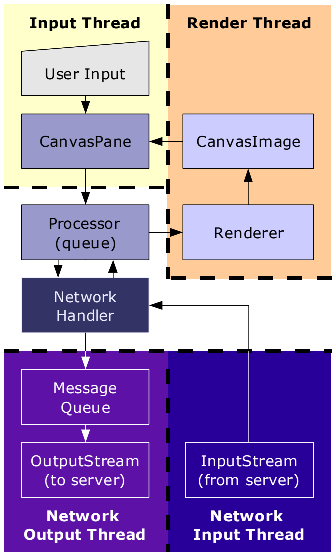


Figure 3. The client uses four threads (user input, line rendering, and network input/output) to separate asynchronous processing and avoid data blocking.

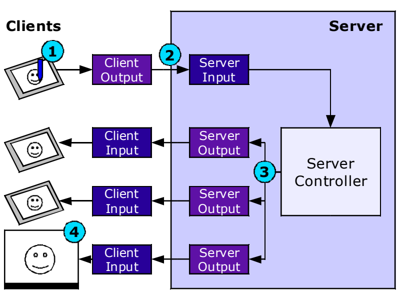


Figure 4. User input (1) is sent from each client to the server through TCP/IP streams (2) where they are broadcast (3) to remaining clients for display (4).

and-Drop interface while our tool emphasizes access to the shared space through the individual inputs.

PebblesDraw is a multi-cursor drawing application that links simultaneous input from PDAs to a single PC display [2]. The Single Display Groupware application allows multiple people to create and annotate drawings at the same time. PebblesDraw's design tried to address the challenges of a single display for multiple users such as sharing a single onscreen tool palette and identifying individual cursors. Our system, by utilizing individual displays, avoids these issues while still supporting a single shared drawing.

Livenotes is a shared notetaking system for group annotation of slides during lecture [1]. Their user study found that their cooperative system increased discussion participation and led to a richer variety of notetaking activity. Like our system, Livenotes utilizes a networked sketching space with individual Tablet PCs. Unlike our system, their system's setting is the classroom, the supported activity is listening to a lecturer without verbal group discussion, and their system's purpose is to facilitate learning.

Olson *et al.* investigated how use of a shared text editor, ShrEdit, affected the process and outcomes of design meetings [3]. In their user study, participants in the experimental condition were each given a computer with a networked group text editor that allowed everyone to see and edit the same document simultaneously while participants in the control condition used conventional meeting tools. The study found that those using the networked tool explored a smaller design space as the tool helped them focus on core issues of the design. While our system is also a networked tool for design meetings, Olson's research examined text editing while we focus on sketching.

System Description

The collaborative sketching system is a drawing application we created with Java 5 run on Tablet PCs and a digital whiteboard. A sketching space is mirrored on all devices, so that a user's drawing, when sketched on their Tablet PC or on the whiteboard, is immediately visible to the rest of the group on their Tablet PCs and the whiteboard. This supports interactive collaborative sketching. For example, in designing a TV, one user can draw the profile of the device while another user starts adding buttons to the same sketch. All users can view and add to the sketch with equal ease simultaneously.

The application provides tools for freehand sketching and erasing of varied line color and thickness and freeform selection to move strokes within the page. Each user's cursor, identified with their name, appears in the shared view when they draw, select, or erase. Users can point out things in the sketching space with a gesture tool. The application supports multiple pages. Navigation between pages affects all displays, literally keeping the group "on the same page."

The Model-View-Controller-based client-server application streams stroke data through a wireless network to synchronize the devices. Multiple threads are used to handle client connections on the server and eliminate visual latency by separating input, line rendering, and network access on the client (see Fig. 3). The server receives messages from the client and broadcasts them to the other clients (see Fig 4). Data is transferred by sending message objects through the

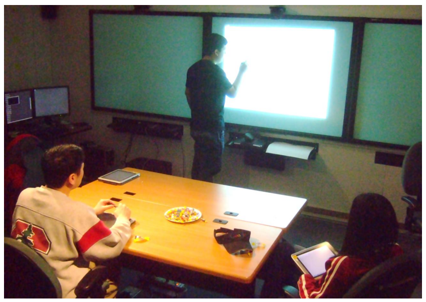


Figure 5. Experiment participants work on a brainstorming task in the control condition with independent devices, Tablet PCs and digital whiteboard (top), and in the experimental condition with networked devices (bottom).

network using serialization. The interface and rendering system were created with Swing and Java 2D.

Evaluation

We hypothesized that in group brainstorming, a shared sketching space accessed through networked personal devices and a digital whiteboard, by lowering the threshold for contribution, will *increase* the total amount of sketching by the group and will *equalize* the individual participation of members within the group.

To evaluate our hypothesis, we conducted a pilot study with groups of HCI and mechanical engineering design students from Stanford University. We performed a between-subjects experiment with five groups in each condition. We provided groups of three students each with individual Tablet PCs and a digital whiteboard. In the experimental condition, the devices were networked and displayed a shared drawing surface. In the control condition, the devices were isolated and displayed independent drawing surfaces, mimicking tools used in conventional group meetings (see Fig. 5).

During the study, we first introduced the participants to the digital tools and the application as they were to be used in their condition and gave them 10 minutes to familiarize themselves with the system. They were then given 30 minutes to brainstorm a design for a multi-function remote controller (for a stove, oven, and stereo) and one minute to present their final design to us. The task was a simplified version of one used in prior research of small design group activity [5].

Following the task, participants filled out a post-study questionnaire comprised of 20 five-point Likert scale questions and six free-form questions pertinent to group participation and dynamics, brainstorming strategies employed, and usefulness of the system for communication and task completion. We then debriefed the participants and informally interviewed them about the experience.

The server application collected performance data by recording a log file of stroke and gesture input.

Results and Discussion

The stroke data collected in our pilot study indicates that sketching contribution among group members tended to be more balanced in the experimental condition. The average standard deviation within a group of the percentage of strokes per user was smaller in the experimental condition ($p = 0.17$, see Fig. 6). The percentage of strokes per user within a group measures the user's relative contribution, and their standard deviation measures the variability of contribution within the group. Contrary to our initial hypothesis, the stroke data indicates that the average total sketching input of the control groups tended to be greater than the experimental groups ($p = 0.21$). Our large p-values are likely due to a small sample size and the experiment being between-subjects.

Most of the control groups followed typical design meeting whiteboard practice, with a self-appointed notetaker being the primary user of the whiteboard and the seated group members occasionally using the Tablet PCs for private sketching that they sometimes would later share with the group. In contrast, the experimental groups rarely approached the whiteboard. On average, 57% of total strokes in the control groups were input on the whiteboard as opposed to 4.4% in the experimental groups ($p = 0.01$). Answers to the

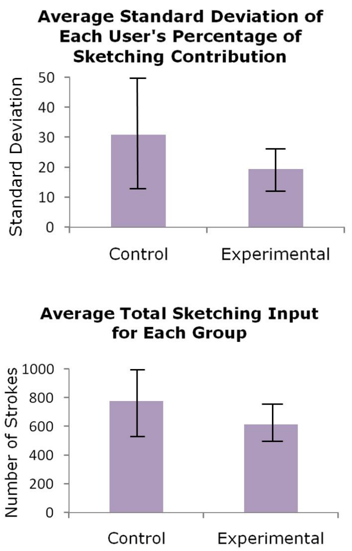


Figure 6. Log file analysis shows that in the control compared to the experimental condition, there was a worse distribution in member contribution (top) but greater total sketching (bottom).

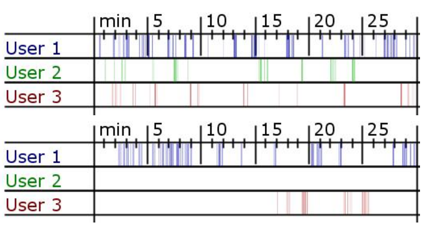


Figure 7. Representations of strokes illustrate the interactive sketching of one experimental group (top) in contrast to the more discrete switching between users of one control group (bottom).

free-form questions and our informal interviews indicate that the digital whiteboard in the experimental condition was primarily used for viewing and group focus. Despite showing the same view as the Tablet PCs, experimental participants said that the whiteboard was important for seeing what everyone was doing and they felt it "tied everything together." Participants said they liked not having to get up to use the whiteboard. Also, one group said that given individual devices, the whiteboard seemed to "hold more power," inhibiting them from using it as freely as they might have.

Participants commented that, compared to traditional tools, the collaborative system made it more obvious and explicit who was contributing. It appears that individual sketching contribution, as opposed to verbal contribution that another group member sketches, results in users feeling very differently about adding to the shared visual space. Participants noted that with the experimental system, they were more conscious of how much each person contributed, and in some cases moderated how much they sketched as a result. One group embraced this aspect and decided to use color to indicate sketch ownership. Furthermore, some participants said that they were more self-conscious of the quality of the ideas that they added to the shared visual space, for example, that they felt an "implicit responsibility" for what they added to be a "real contribution." Some participants said that they thought longer about ideas to make them more complete before proposing them to the group with a sketch.

This greater consciousness of quality and quantity of contribution, resulting in self-moderation of sketches added to the shared space, may explain why the net sketching contribution was less in the experimental condition. Reduced contribution contradicts the "go for quantity" tenet of brainstorming. We speculate that this increased awareness could be due to a more explicit identification of who contributes what (through watching the process of sketching as well as the resulting sketches being identifiable) or to the fact that sketching, which creates a visual artifact, is a more formal contribution than verbal expression.

We observed more interactive collaborative sketching in the experimental condition (see Fig. 7). Group members would build off one another's drawings by annotating an existing sketch or drawing an alternative idea next to it. In one group, all three members built lists of ideas, each adding items. However, in other groups, the conventional brainstorming role of a recorder for the group naturally emerged.

Participants noted that they liked being able to sketch an idea while someone else was speaking or drawing. With conventional tools, a second person approaching the whiteboard would demand group focus. Drawing with our system allowed people to get down their idea without interrupting the discussion, with one participant describing it as a way of "raising your hand."

One noted consequence of our system that participants cited was the reduction of face-to-face communication. Participants became so engrossed in looking at the sketch on their Tablet PCs that they looked up at each other less. However, we note that current conventional whiteboard practice also struggles to support face-to-face communication between members. The recorder must turn away from the group to write on the whiteboard and the seated group members orient towards the whiteboard instead of each other to view it.

Despite having an unlimited virtual drawing space, the system has a limited display real estate afforded by the Tablet PCs. Participants mentioned that it was sometimes difficult to manage the space as they often wanted to keep a large number of sketches in view.

Conclusions and Future Work

Results from our pilot study suggest that shared sketching with individual inputs affects brainstorming. A larger experiment is needed to fully evaluate our system and confirm our observations with statistical significance. In addition, we would like to evaluate the outcomes of the brainstorming task in order to draw more concrete conclusions about the benefits our system brings to group brainstorming.

We would like to create a hybrid system, incorporating a private space with the shared public space, an analog to logbooks. We believe a space to develop ideas privately while keeping the shared space in view will help address the self-consciousness some participants reported about the current system. Keeping private and public views adjacent supports private sketching without distancing users from the group discussion and affords easy transfer of ideas between the two spaces.

We are also interested in further utilizing the digital whiteboard, for example, as a central focus or to expand the number of viewable sketches. Possible exploration could include a means of forcing attention to the digital whiteboard or using the digital whiteboard to display multiple pages and navigate larger spaces.

Our pilot study suggests that in a group brainstorming session, a shared sketching space accessed and viewed through networked Tablet PCs and a digital whiteboard evens out individual participation within the group because the personal devices lower the threshold for contribution. Unexpectedly, the results indicate that such a system lessens the total group sketching when compared to groups in the non-networked condition. Qualitative observation suggests that brainstorming with a collaborative sketching tool increases awareness of the quantity of relative contribution and the quality of contribution shared with the group.

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