Abstract—The use of current computers for collaborative work in face-to-face meetings is limited because the architecture of most computers is designed considering only personal use. This paper discusses collaborative working by organizing information represented on cards, one of the commonly-seen activities in both business and education. The authors developed a prototype system that computerizes this activity, to enhance reuse of the results of collaborative work. The prototype system is implemented as an application of Single Display Groupware (SDG) that allows multiple users to manipulate shared information on a display.

Keywords—CSCW; CSCL; Single Display Groupware

I. INTRODUCTION

In both business and education we often have group activities in which members collaboratively gather information and organize it through face-to-face discussion. One typical example is brainstorming done as a group. The members of the group collect their ideas, written on many small cards or sticky notes, and then organize them the cards graphically on a whiteboard or a large sheet of paper using some technique such as the K-J method[1]. With this technique we can easily share information, add facts and ideas, and reorganize them by trial and error. Such a process first widens the ideas and then gradually converges them. Figure 1 is an example of such an activity. Photographs are also often used for brainstorming, thanks to digital cameras and the ease of digital printing.

The media involved in brainstorming (such as pens, cards, printed photographs and white boards) are intuitive and easy to use for most people, and the process can be carried out in ordinary rooms. However, the results are presented on the white boards (or large sheets of paper) and they are difficult to transport or preserve. Furthermore, to record the dynamic process of information organization using such physical and static media is difficult. For these reasons we face difficulties when reusing the results of brainstorming activities in downstream activities such as project development, improvement of the process, and reflection on the learning that occurred.

In this paper, we propose a computerized tool for collaborative organization of information to enhance reuse of the results. The paper is organized as follows. After this introduction, in Section II we give an overview of Single Display Groupware (SDG) and the socialized computer (SC) project carried out by the authors aimed at the computerization of collaborative work in face-to-face environments. In Section III we discuss the process observed in collaborative brainstorming and the requirements for a computerized tool. An implementation of the tool, called Multi-Mouse InfoBoard (MMIB), is explained in Section IV. Section V explains the experiment of using MMIB, and the results are discussed in Section VI. Section VII presents concluding remarks.

II. SINGLE DISPLAY GROUPWARE/SOCIALIZED COMPUTER

The use of computers for collaborative work in face-to-face environments is quite limited. We think there are two barriers to using computers for such activities.

One is the size and resolution of displays used to visually share information. Reproducing the information shown on cards/notes on a white board requires a very high-resolution electronic display, and sharing between several members requires a display sized as big as a white board. We can now use large and high-resolution LCD panels or projectors, or multiple tiled LCD panels to achieve a larger and higher-resolution display. Hence this first barrier is decreasing.

The second barrier is the architecture and software of the personal computer. Current personal computer interfaces
offer us sophisticated environments for personal use of computers; they are designed considering only that the computer be used by a single person. Hence, even when we bring a computer to collaborative work to share information on a screen, only one member can manipulate the computer and the other members have to perform operations with information on the screen indirectly by asking the member manipulating the computer.

To overcome the second barrier to collaborative use of computers in face-to-face environments, various types of user interfaces/systems have been proposed. Tabletop computers have been developed for such purposes along with increasing computing power. In Xerox PARC’s Colab project[3], participants are seated around workstations arrange on a table and interact with each other using table-centric devices. The iRoom project[2] supports interactions more directly on tables and vertical surfaces.

Stewart et al. proposed Single Display Groupware (SDG)[4] which is a model for supporting collaborative work sharing a single output channel, e.g., the display. SDG users can not only operate a single system cooperatively, but can also break into personal work and take over. Caretta[5] which is categorized as a kind of SDG integrates personal and shared spaces to support face-to-face collaboration. It uses PDAs and a sensing board to link the shared space and personal spaces. While PDAs support users easily, displaying personal work spaces without disturbance by other users, they diminish the advantages of SDG in flexibility and ease of set-up. Pawar et al. have developed software that allows multiple mouse pointers to share the monitor for educational use in developing countries[6]. Ueda has also developed Multi-mouse middleware toolkit (MMTk) which enables the use of multiple mice in applications coded specially for that environment[7]. Similar middleware called SDGToolkit has been developed by Tse and Greenberg[8]. Hutterer et al. proposed Groupware Windowing System (GWWS)[9], and MPX which is an implementation of GWWS for the X Window System. Moraveji et al. have also developed an SDG system and studied its performance with many users[10], [11].

Among these, as a computing technology to support collaborative work, we are interested in SDG because it can be used just with commonly-available devices such as personal computers, mice and keyboards, and therefore we can develop systems that are cheap and portable. It is important to obtain feedback from actual users of the developed systems to improve the design of the user interface based on experience.

The authors are also studying SDG in the ‘Socialized Computer’ (SC) project. It puts more stress on the concept of SDG as an alternative to the usually-personal computer. We have developed a Multi-Mouse Drawing Tool and a Multi-Mouse Quiz System and carried out a field study using the systems[12], [13], [14].

III. ORGANIZING INFORMATION THROUGH FACE-TO-FACE COLLABORATION

This section gives an overview of the process of collaborative work by organizing information presented on multiple information cards and discusses requirements for computerizing this work. Here ‘information card’ means a handy small piece of paper (such as 5” × 3”) or sticky note on which words, phrases or sentences can be written.

We have experience with several workshops of ‘Participatory Production’ in collaboration with small manufacturing companies. These workshops aimed at empowering end-users to create something by themselves that met their particular needs. With university students as workshop participants we have made prototypes of umbrellas, bicycles and bags that support campus life. In the workshops we first asked students to collect findings in fieldwork observing the real circumstances of use and to post ideas, as solutions to observed problem situations, using information cards. The participants then organized the information cards on a white board to make concrete product designs with the help of a facilitator. Referring to the organized information, the participants then made mock-ups of products and presented their ideas to all participants including people from manufacturing companies. When the workshop is finished the organized information is recorded by digital camera. We sometimes carry out workshop analysis meetings among participants using the recorded images. Since they are just photographs, analysis of words and subsequent re-organization of the information are quite difficult.

A. Operation of Collaborative Brainstorming

We assume the following process of collaborative brainstorming as an example of the work to be supported by a computer.

1) Brainstorming is carried out on a predetermined theme with a facilitator who manages the process.
2) First, the facilitator explains the theme and calls for ideas from the participants.
3) The facilitator gives the participants time to think about the theme. Each participant writes ideas on cards using one card for each idea.
4) The facilitator gives each participant an opportunity to talk about their ideas as they put their cards on the white board.
5) After all participants have spoken, the facilitator calls for further ideas.
6) The facilitator repeats steps 3) ~ 5) as necessary.
7) During the above repetition, the facilitator and the participants try to organize the ideas by moving the information cards according to relationships between them, drawing the relationships on the white board with colored markers.
8) Finally the facilitator reviews the organized information on the white board, summarizes the discussion, and closes the brainstorming.

In practice, some actions are taken according to the outcome of the brainstorming. The participants may review the results to make the ideas concrete, or to include additional ideas. The participants may gather again for further discussion based on the results.

B. Requirements for an Information Organizing Tool

Considering the above process, we know the following:

- The ideas obtained may be reused for other opportunities.
- The ideas obtained may be organized and edited.
- If the results are presented on a large screen physically, it is difficult for the members to bring the results back to their offices or home.

By supporting the above process of brainstorming using computers, with the results represented by electronic media, we can achieve the above requirements. For the computerized tool, we want the following:

- Information cards can be freely posted on the screen.
- The location of the cards can be changed to organize the information.
- Relationships among information cards can be drawn on the screen.

It should be noted that multiple members participate in the brainstorming and hence it is natural to allow all participants to manipulate the information cards. This suggests that implementing the tool as an application of SDG is promising.

IV. IMPLEMENTATION OF MULTI-MOUSE INFOBOARD

We have developed a prototype application of SDG called ‘Multi-Mouse InfoBoard’ (MMIB) that supports the aforementioned collaborative information organization during brainstorming. MMIB is implemented as a Windows application using the .NET framework. SDGToolkit[8] is used as middleware to handle input from multiple independent mice.

This system assumes that it operates in collaborative work with a facilitator. While multiple mice are connected to the computer, we connect only one keyboard and its use is restricted to the facilitator. Input from the keyboard is bound to a particular mouse operated by the facilitator, and we assume the following operation.

1) All the participants express their ideas in some way.
2) The facilitator creates the information cards and writes down the proposed ideas with the keyboard.
3) All the participants try to organize the information cards by moving them with their mice collaboratively. They can also express relationships among the information cards by freehand drawing, connecting cards with lines, and grouping the cards in nestable structures.

Figures 2 and 3 show example operation of the MMIB. In this case, six mouse pointers are shown on the screen with one facilitator and five participants operating the system. The facilitator clicks his mouse to be able to enter text onto a card from the keyboard.

Figure 2 shows an early stage of the activity. The facilitator finished inputting cards and has distributed them on the screen in no particular order. Figure 3 shows the organized information with MMIB. Freehand drawings are added, relationships among cards are shown by lines connecting them and by nested structure enclosing some cards. In the nested structure, one card (a parent card) is used as the label of a category. If a card is clicked by a particular user, the background color of the card is changed to the color assigned to that user. In the nested structure, by clicking on the parent card, all the cards belonging to the category can be selected and moved. In Figure 3 only a single word is written on each card, even though cards can contain phrases and sentences. The size of the card is adjusted automatically according to the length of the string, but the user can also change the size of a card manually by a mouse operation.
Table I

<table>
<thead>
<tr>
<th>Task</th>
<th>1st</th>
<th>2nd</th>
</tr>
</thead>
<tbody>
<tr>
<td>First task name</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>Applied name</td>
<td>P</td>
<td>Q</td>
</tr>
<tr>
<td>Applied mode name</td>
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<td>limited</td>
</tr>
<tr>
<td>Second task name</td>
<td>Y</td>
<td>X</td>
</tr>
<tr>
<td>Applied mode name</td>
<td>unlimited</td>
<td>unlimited</td>
</tr>
</tbody>
</table>

V. PROBLEM FINDING EXPERIMENT

In this section we explain about an experiment for finding problems concerning the ease or difficulty of operating the MMIB in collaborative brainstorming.

A. Experimental settings

Six subjects, students in the Graduate School of Informatics, participate in this experiment. They are separated into two groups named Group P and Group Q, with care taken to distribute characteristics such as age evenly between them. Each group includes a facilitator (the first author).

We set a 40-inch display in front of a table on which subjects and facilitator are seated on 4 chairs. Distance from the seats to the display is about 1.5 meters, to prevent any direct indication of objects on the display.

We prepared two tasks called Task X and Task Y as follows:

- **Task X**: You are organizers for a year-end inter-laboratory party. Your plan is that you and other laboratory members will cook for yourselves in the kitchen. Let's consider this plan around menus, ingredients, workflows, arrangements, etc. The party is going to happen seven days from now from 18:00–20:00, and 30 staff and students would like to participate in this party. There is no other condition.

- **Task Y**: You are organizers for an inter-laboratory research camp. All planning and scheduling are in your charge. Necessary conditions are that you have to reserve time for any kind of presentation and that the camp will be held within the year. Let's consider a destination, activities, schedule, etc.

We also prepared two modes of control of the MMIB. One of the modes is called limited mode similar to the use of an ordinary personal computer. Participating subjects do not touch the mouse and therefore do not control any object on the MMIB. The other is unlimited mode using the environment of SDG in which the computer can be operated by each subject. In a limited mode session the facilitator organizes cards and expresses relationships.

In this experiment we carry out two trials by different groups. Each trial includes two tasks, each performed in limited and unlimited modes. We regard the first task in the limited mode as a demonstration of MMIB by the facilitator. Table I shows the relationships between the groups, the tasks and the modes. Although we set aside a nominal duration for carrying out each task of 45 minutes, the facilitator can extend the finishing time if required by the subjects to finish their task. In the first ten minutes, the facilitator asks the subjects to write down around ten ideas. After that they are asked to present the ideas, the facilitator inputs them onto cards, and then the brainstorming is carried out. The facilitator will add more cards if needed. After both tasks are finished, participants complete a questionnaire about usability and a comparison between limited mode and unlimited mode, before joining a short group interview.

The questionnaire contains twelve questions. Seven questions are about usability, six being on a five-point scale and one being a free description. The questions are as follows:

1. Can you understand the layout method presented by MMIB?
2. Can you discriminate between your cards and others?
3. Can you discriminate relationship marks (arrowed lines and grouping rectangles)?
4. Are the arrowed relation methods easy?
5. Are the grouping methods easy?
6. Are the grouping methods easy?
(1) to (3) that MMIB made the subjects feel it was easy to discriminate objects on the display. On the other hand, we see from question (4) to (6) that MMIB made them feel it was difficult to manipulate cards and relationships. We found little use of arrowed relationships. Participants said in the interview that they did not know where to use the arrows.

As shown in Figure 6, opinion was divided equally between the two modes. One subject answered in free description, “I could pay proper attention to others’ opinions in limited mode. Unlimited mode made me cling to my ideas and opinions because of having individual control.” Another subject answered, “Unlimited mode lowered the operation hurdles compared to giving verbal instructions to the facilitator in limited mode.” Some other subjects also answered similar comments. Thus, on one hand, limitation of control led them to discussion, but at the same time the limitation was sometimes distracting because of the difficulty of manipulation.

In limited mode the subjects attempted to indicate a card by reading its initial text. Gradually they began to indicate cards by initial words on the card with the position on the display such as top, bottom, left or right. Conversely, in unlimited mode, subjects could indicate a card directly using their mouse cursors. One subject said, “Although I couldn’t often convey my intended manipulation in the limited mode, and it caused the layout to feel not to follow my wishes, I was satisfied with controllability in unlimited mode.” Unlimited mode enabled indication of individual cards better than limited mode.

VI. DISCUSSION

A. Examination of the Results

The current MMIB has too many bugs because it is a prototype system, and some of them appeared in the experiments in front of the subjects. Since this caused stress for the subjects and confused operations, the impression of MMIB was not so good.

In the results comparing limitations, an SDG environment as used in unlimited mode scarcely beat the ordinary PC environment reproduced in limited mode. Subjects’ comments in the interviews were different from our assumptions about their use of multiple mice. They indicated that they wanted to input cards in parallel in limited mode because of the shorter input times. On the other hand they preferred exclusive access when organizing cards for the reason mentioned above, because of losing track of others’ manipulations. This represents a need for an ‘exclusive’ button on the screen, for example.

Limited operation of mice caused better attention to discussion. Actually, our previous research using a Multi-Mouse Paint Tool showed that limited operation, such as a when a single mouse was available, encouraged more attention than a fully-controlled operation such as when having...
multiple mice. Introducing this limitation would be good design, letting the facilitator keep participants concentrated on the discussion.

Displaying mouse cursors and providing mice for manipulations are two different problems. In this experiment, the subjects immersed themselves in the task because they could manipulate cards. However, they would need mouse cursors to indicate focus on a particular card. If they couldn’t manipulate using mice, but could indicate using cursors, this limitation would cause them to become more actively involved in discussion.

B. Remaining Problems

In this paper we conducted only a comparative study of limited and unlimited modes in the use of MMIB; comparison of MMIB with conventional methods of using physical devices, such as sticky notes and whiteboards, is a subject for future study. However, compared with our experience of the conventional method, manipulation of information card arrangement by multiple users with multiple mice illustrates some differences with the conventional method. These may be caused by differing physical characteristics such as speed of movement and interference between multiple users in the conventional method, and the light and free motion with electronic devices. The result of our study shows that such characteristics of the electronic devices may even hinder information sharing among the users, while it enables easy and quick manipulations by each user.

Another important problem in SDG is simultaneous input from keyboards by multiple users. SDGToolkit allows separate handling of multiple keyboards. However, it provides applications only with the raw key codes pressed by the users. Japan and other east Asian countries use Kanji, and other characters native to particular languages. Current personal computers support sophisticated conversions from alphabetical expression to these native characters. In the SDG environment, we can’t use these built-in functions, and we have to cope with the character conversion problem by ourselves.

To handle pictures/photographs on the information cards is another remaining problem. Photographs taken during field work, for example, is an important medium for expressing situations difficult to write in a few words and for stimulating discussions during brainstorming. Treatment of photographs requires better computing performance, and we have to enhance the performance of our system. While it is still a single-user application running on a personal computer, Sunaga et al. have developed a system to organize photographs from various aspects, and carried out workshops using it[15], [16]. This gives hints of a design in our system for treating photographs.

Furthermore, the current implementation of MMIB mainly focuses on the function of the software. However, graphical design of the system is also an important issue to guide users towards understanding the organized information and manipulation of it.

VII. Conclusion

This paper discusses a tool for collaboratively organizing information represented as cards on a shared display. We have developed a prototype system that supports brainstorming by several users in face-to-face meetings as an application of Single Display Groupware (SDG).

We found problems related to limitation of mouse manipulation. We also discussed some remaining problems to be studied in the future.

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REFERENCES


