PAPER   *Special Section on Knowledge Discovery, Data Mining and Creativity Support System*

GKJ: Group KJ Method Support System Utilizing Digital Pens

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SUMMARY   Practitioners of the Jiro Kawakita (KJ) method, a method for organizing ideas, typically use paper labels and four-colored ball-point pens to record their ideas during the creative thinking process. A similar approach is used in group KJ method sessions; however, the effectiveness of capturing and sharing the diagrams and information is limited because of the large amount of paper required. Considering the merits of the conventional paper-pen approach and the demand for quick sharing of diagrams after a session, we designed and implemented a system to digitize group KJ sessions—not just the diagrams but also the details of the creative process. We used digital pens during the session to capture the position and orientation of labels as well as their content. We confirmed the efficiency of our system by applying it to several GKJ sessions.
key words: CSCW, creative meeting, label work, KJ method

1.   Introduction

We often use small paper cards or Post-it notes to organize our thoughts and ideas. Cards are generally arranged or organized on a table or adhered to a wall. Proposed by Jiro Kawakita [1] *, the KJ method is one of the technologies utilizing this approach. The use of paper cards has two key advantages: (1) moving the cards by hands is easy and intuitive; and (2) groups of users can simultaneously access or rearrange the cards. Therefore, such card-based activity is commonly used for brainstorming and organizing ideas.

Archiving the creative thinking process and the outcome (usually an affinity diagram made up of cards) and sharing them for continuous evolution are difficult primarily because of the large number of cards. For effective sharing, digitizing the outcome diagram is mandatory. It can be captured by a digital camera, but the captured images are fixed, and therefore not suitable for continuous evolution. For further evolution, the cards should be separate atomic entities within a larger image or diagram. In a typical group KJ session, one of the participants digitizes the outcome diagram by inputting all card content and arranging them using a keyboard and a mouse. The additional input task burdens the participant and is very time consuming. If we could instead digitize such outcome diagrams automatically, it would not

be a burden to participants and greatly improve the participants' ability to evolve and refine the ideas.

In this paper, we propose such a method for capturing the location of the paper cards using a small and portable facility. The captured location is then used to digitize the outcome diagrams and reproduce the card-organization process after the session ends. We have developed a system on the basis of our method to easily record the outcome and details of the creative process. We confirmed the effectiveness of our method, as well as the system, over the course of several group KJ-method sessions.

2.   Background: KJ Method Activity and Diagrams

Our proposed method primarily focuses on creating affinity diagrams using the group KJ method. In this section, we describe details of the conventional KJ method.

2.1   Radial Affinity Diagram

Figure 1 shows a radial affinity diagram, which is used to achieve both consensus and understanding among participants in the discussion. First, a theme or a key problem is placed at the center of the base sheet. Second, participants position their cards in turns, aligning similar cards in a spoke-like fashion. Cards are related by links, for which a paper clip is often used. Third, participants fix the card positions and links.

The radial affinity diagram is similar to the Mind Map [2] **, but the KJ method differs in the grouping and organizing of cards.

2.2   Grouping Cards for Abstraction and Organization

Figure 2 shows a snapshot of grouping cards for abstraction and organization. The purpose of this grouping process is to construct appropriate structure and relationship of the cards in bottom-up manner. First, participants randomly arrange all cards on a grid. Second, they read through the cards and pick up two cards that are relatively similar. The similarity can be decided by personal intuition through conversation with the cards with *Zen* mind. The selected cards are placed

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*KJ method is a registered trademark of Kawakita Research Institute.
**Mind Map is a registered trademark of the Buzan Organisation.

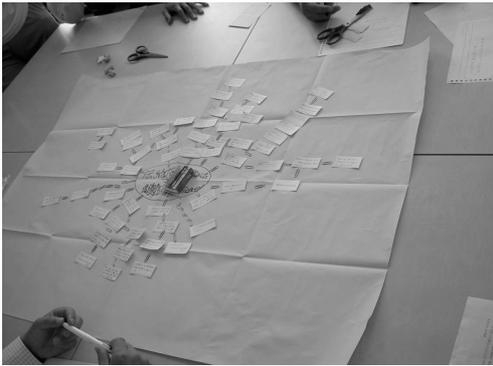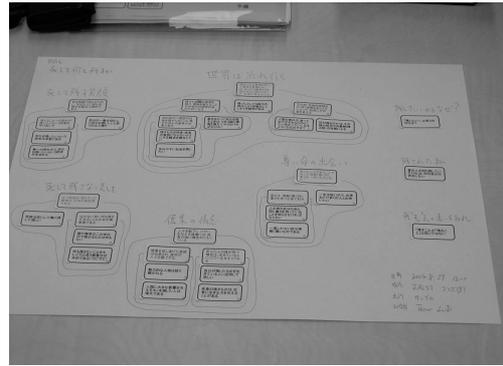**Fig. 1**　Radial affinity diagram.
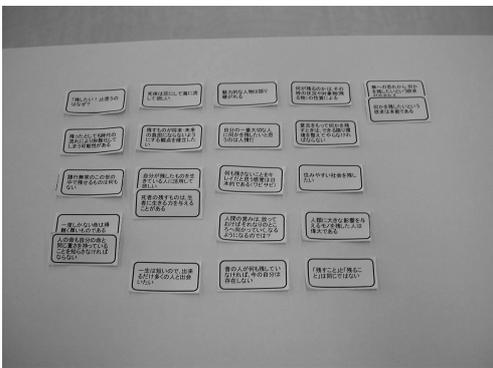

Fig. 3　Affinity diagram.

Fig. 2　Grouping cards.

Fig. 4　Digital pen and cards.

Fig. 5　A line drawn over card borders is separated into three separate lines.
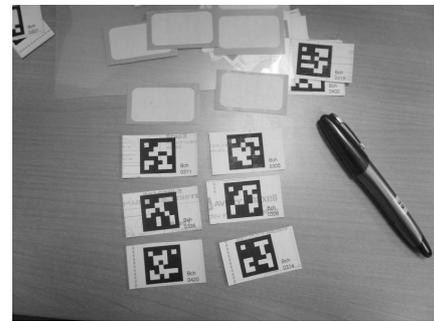
close to each other (shown as overlapping cards in the figure). After the pairing, participants add a title card for each pair. A suitable title conveys the meaning and essence of the paired cards without being very abstract or vague. The title card and the two paired cards are placed in a pile and clipped together. The three cards should be handled as a new card that is labeled with the title. This process is repeated until the total number of piled cards is between five and nine.

2.3　Creating an Affinity Diagram

After grouping the cards, participants unpack the piled cards and place them on the base sheet, carefully preserving the hierarchical structure of the cards. As shown in Fig. 3, cards are encircled with red/blue/green/black circles. Next, participants provide a meaningful phrase or sentence to summarize the top-level groups. The final diagram can represent the true nature of the problem. Also, it can be used to share their thoughts and to find hidden issues and standpoints.

3.　Proposed Capturing Method

Our method utilizes Anoto-based pens (Fig. 4) to record card-based activities. The Anoto-based pen can capture drawings on paper cards and a base sheet. The position of the drawings is recognized by scanning patterns of dots on the paper. Because of the unique features of the patterns, the
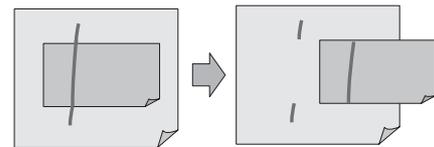
method can distinguish between the data of the drawings on the cards and those on the base sheet. In addition to these characteristics, the drawings can be used to specify the positions, orientations, and groupings of the cards on the base sheet.

3.1　Principle

When a user draws a line that covers the base sheet and a card on top of the base sheet (i.e., the left portion of Fig. 5), the pen recognizes the line as three separate lines (i.e., the right portion of Fig. 5); however, if these lines are generated at almost the same time, we consider the paper card placed so as to connect the three lines, as shown in Fig. 6. We call this pen drawing operation over the base sheet and the card *scanning* and each connecting point *a joint*. If one joint is detected, the position of the card can be determined. If two or more joints are detected, our method can determine not only the position but also the orientation of the card, as shown in Fig. 7.

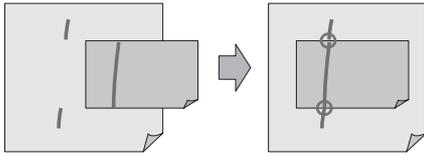Enhancing this technique, we can recognize the over-

Fig. 6   If the three lines of Fig. 5 were drawn at approximately the same time, the card would be located as shown in the right portion above, with joints shown as red circles.
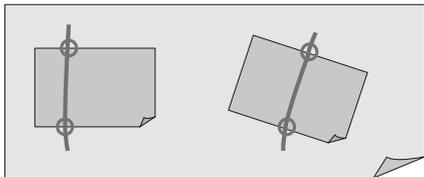

Fig. 7   If two (or more) joints are present between card and the base paper, recognizing the card orientation is also possible.
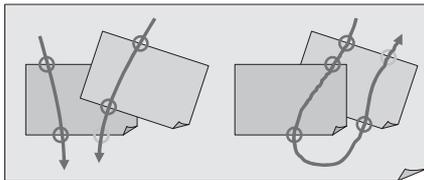

Fig. 8   Given multiple overlapping cards, detecting each card's position, orientation and overlapping state is possible given at least two joints per card.
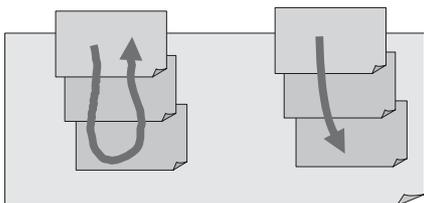

Fig. 9   Scanning operations for grouping (left) and ungrouping (right) sets of overlapping cards.

lapping state of multiple paper cards, as long as two joints are extracted for each card. Figure 8 shows two such examples. To eliminate unnecessary pen markings on the paper during scanning, we propose using a transparent plastic sheet while scanning. The Anoto-based pen can still scan dot patterns when such a transparent sheet is used.

A similar method was proposed by Ref. [3] as part of their research on digitized experiment-record notes and digital paper bookmark tagging in the CoScribe system [4]; however, in our approach, we introduce additional pen gestures called grouping and ungrouping to edit the card structure. As shown in the left portion of Fig. 9, grouping is performed by a continuous round stroke from the top-level card over the child cards, then back up to the top card. This grouping operation should be intuitive for users since it is derived from the "surrounding of the cards" metaphor.

As shown in the right portion of Fig. 9, ungrouping can

Table 1   Processing of drawings in our method.

Drawings on card	Handled as normal drawings on the card.
Drawings on base sheet	Handled as normal drawings on the base sheet.
Drawings on both card and base sheet	Handled by determining position and orientation of card (s).
Drawings on multiple cards (round stroke)	Handled as grouping operations.
Drawings on multiple cards (single stroke)	Handled as ungrouping operations.

be performed by a continuous single stroke from the top-level card of a group down through its child cards. This operation parallels a user's natural sweeping motion to ungroup the cards. These grouping and ungrouping operations can be used for creative card-based activities, especially for creating affinity diagrams using the KJ method [1]. The aforementioned processes for handling drawings and gestures on cards and base sheets are summarized in Table 1.

While a digital camera can also record the paper sheet images in detail, the reusability of the card content is crucial for creative tasks. Furthermore, atomic data should be provided to support the ability to later group, ungroup, and move cards around. In particular, an authentic KJ method involves follow-up procedures for refinement and deepening.

3.2   Merit

Merits of our proposed method include the following:

1. Without being forced to use PCs (which might be counterproductive to the creative and collaborative process), participants can edit affinity diagrams with digital pens and transparent sheets. These devices are more natural and intuitive than using a PC. Furthermore, a digital pen is inexpensive compared to a typical PC.
2. Our proposed method is suitable for card-based creative thinking. Most participants with experience of the KJ method are accustomed to handling cards. Therefore, our method does not disturb the concentration of the participants by introducing a new format or medium.
3. Participants can contribute to a group session by both expressing their ideas and controlling card positions.
4. Since the archived diagram manages cards separately, the diagram can easily be revised. Still images taken by a digital camera can capture the diagram; however, they are static.
5. Because of the wireless transmission of the digital pen, the method accepts simultaneous activities by multiple participants.
6. Unlike the Designer's Outpost method [5], which does not allow moving multiple cards at once, our method can distinguish multiple moving card events.

7. The mechanism of our method is simpler than that of other AR systems [5], [11]. In particular, our method has the advantage of high system mobility because of the small lightweight devices it employs.

4. Related Work

There are various methods for augmenting discussion and creative thinking in groups. Brain writing [6] is a group creativity technique aimed to address the potential deficiencies of brainstorming proposed by Holiger. Mind Maps [2] utilize visual techniques to structure ideas and encourage brainstorming and problem solving. Spatial Hypertext [7] is a document composing method that represents relationships by spatial proximity and visual cues. Similarly, tools to support the KJ method, such as the KJ Editor [8], GUNGEN [9], and D-ABDUCTOR [10], are proposed. These tools enable users to handle virtual cards and Post-it notes on a PC. These tools are effective in digitizing the card-organizing task. Also, they address the issue of archiving and sharing; however, using a mouse and keyboard as input is often unsuitable for group meetings and collaboration. We consider conventional (i.e., non-PC) card handling as advantageous for the augmentation of creative thinking.

Klemmer et al. proposed the Designer's Outpost system [5] to capture the flow and transition of Post-it notes on a wall-sized screen. We also developed a related system to relieve the occlusion problem of the outpost system by using a glass surface with controllable transparency [11]; however, the outpost system's large size makes it difficult to move, rendering it inapplicable for digitizing activities in casual and impromptu meetings normally held in knowledge-creation companies and research laboratories.

5. GKJ System

With our proposed method, we have developed Group KJ (GKJ), a system to facilitate the recording and archiving of card-based activities, such as the KJ method, in groups. GKJ accepts scanning and drawing by an Anoto-based pen on paper cards and immediately updates the status of virtual cards, which correspond to the real cards. The status (i.e., position and orientation) of the virtual cards is recorded with a timestamp to record the processes of the activity. Once the archive is created, sharing is immediate.

As shown in Fig. 10, our GKJ system comprises the following components: (1) Anoto pens; (2) an L-Box Digital Pen Gateway System (DPGW) [†]; and (3) a GKJ editor. The L-Box DPGW collects pen data from multiple pens simultaneously via Bluetooth connections and sends the data to a MySQL table in a neighboring PC. The GKJ editor checks the updated data and processes the data to construct a digital representation of the current paper-based status.

The GKJ editor accepts inputs from a mouse and keyboard for further editing tasks on the virtual cards. In this manner, participants can further review and refine their ideas
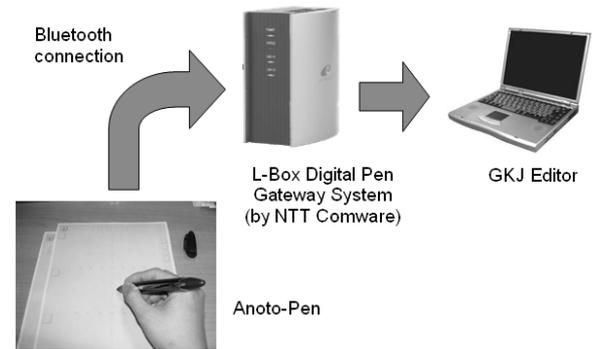

Fig. 10 GKJ system overview and data flow.

by editing the virtual cards. GKJ also provides a function to print out the virtual cards for a session.

Figure 11 shows the initial screen of the GKJ editor in which we assume there are five participants. Therefore, five workspaces are presented. Each workspace comprises base sheets (gray rectangles) and cards (yellow rectangles). The larger number (01-05) indicates a workspace-ID, which corresponds to pen data from the same pen-ID; therefore, the workspace-ID identifies each participant.

The smaller number (01) shows a transfer-ID, which represents an additional destination of the pen data. If the transfer-ID differs from the workspace-ID, the pen data are placed in both workspaces indicated. In the example of Fig. 11, all pen data with pen-IDs 01 through 05 are sent to workspace 01, meaning that all participants (01-05) work together on workspace 01 with the assembled pen data.

If instead the transfer-ID is equal to the workspace-ID, it means that the participants work individually. We included this feature because in a group KJ method session, group and personal work styles are often changed to improve efficiency and increase initiative among participants. When the work style changes from being a group activity to an individual, participants require personal copies of the cards. Using the printing function of GKJ, they can easily obtain copies.

5.1 Typical Procedures of a GKJ Session

The following steps summarize typical procedures of a GKJ session:

1. The organizer distributes blank cards on which the participants write their ideas. When they send the pen data, the GKJ workspace displays the written ideas in card areas.
2. The participants create a radial affinity diagram (described above in Sect. 2.1), which consists of nodes

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[†]L-Box is an ultra-small Linux Server. Digital Pen Gateway is an access point software running on the L-Box. The L-Box DPGW can accept simultaneous wireless data transmission from multiple pens. The maximum number of pens depends on the configuration and the number of installed Bluetooth dongles. We utilized 42 pens for the GKJ. http://www.anoto.com/partner-news-1.aspx?releaseid=2487
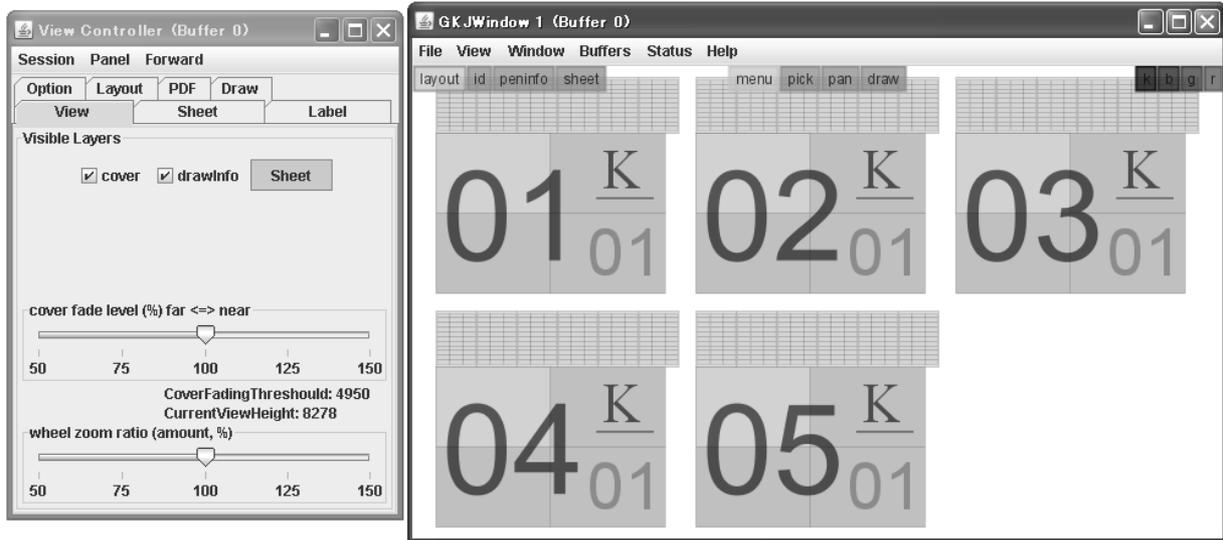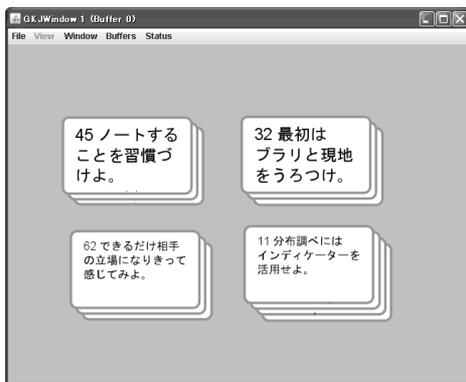
Fig. 11　　Initial screen.

Fig. 12　　Piled cards in the GKJ.

(cards) and links. Participants put their cards on the base sheet in turns. If necessary, the organizer asks the participants to confirm their meaning and changes the order of turns. Each participant scans each card after its position is fixed and writes additional cards inspired by the content of other cards. The GKJ workspace displays the updated status of the radial affinity diagram as changes are made.

3. When the radial affinity diagram is created, participants share their understanding of the cards.

4. Participants identify pairs of cards that are similar (see Sect. 2.2 above). During the pairing process, participants are expected to scan the moved cards.

5. Participants create title cards for the selected pairs by writing on new blank cards. Next, they align the title cards and paired cards and group them with circular pen gestures. After the grouping operation, the cards are placed in piles and clipped together. The GKJ system displays the piles of cards by showing the top card and additional card edges, as shown in Fig. 12. This process is repeated as per the conventional KJ method.

6. After the cards are grouped, participants move to the

unpacking phase (see Sect. 2.3 above). The traditional KJ method requires an additional marking on the top-level label to preserve the hierarchical structure of the card. Moreover, participants were required to estimate the necessary area for arranging all unpacked cards in a layout. If the estimation failed, participants had to carefully move many cards. The GKJ system eliminates this layout task, because participants can simulate the unpacking process on a PC screen. After checking the layout of the virtual cards, they can unpack the cards on the physical base sheet.

After the cards are grouped, the participants move to the unpacking phase (see Creating an Affinity Diagram, described in Sect. 2.3). The former KJ method required an additional marking on the label to preserve the hierarchical structure of the card. Moreover, the participants were required to estimate the necessary area for arranging all the unpacked cards in a layout. If the estimation failed, participants had to carefully move many cards. The GKJ system eliminates taking care of the layout, because the participants can simulate the unpacking of the cards on a PC screen (see Fig. 13). After checking the layout of the virtual cards, they can place the cards on the physical base sheet.

5.2　Additional GKJ Editor Functions

Our GKJ implementation usually represents label text on cards as images, but it can be converted to typed text by utilizing a handwriting recognition engine. We linked our GKJ system with such a recognition engine and tested its effectiveness. Figure 13 shows an example of a final affinity diagram with automatically converted text.

The surrounding circles shown in Fig. 13 are calculated from virtual card positions and their corresponding groupings. Participants can modify the affinity diagram further
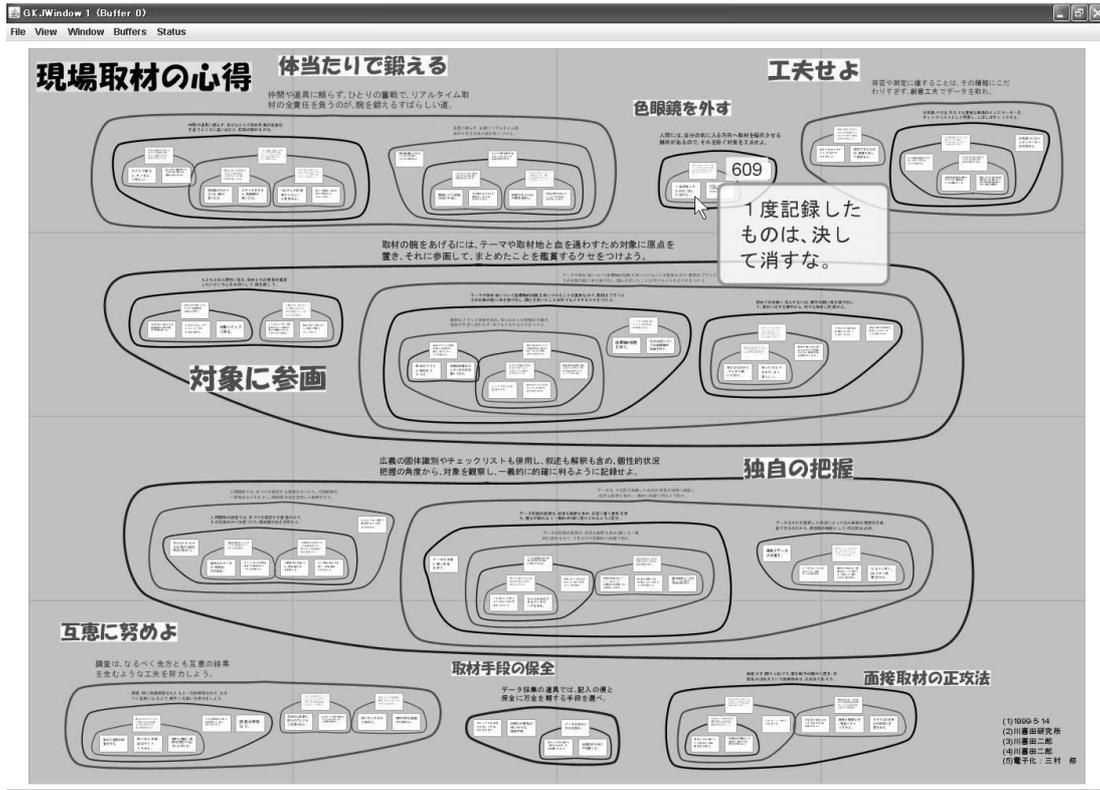
Fig. 13 Final state of an affinity diagram.

via the GKJ editor. Furthermore, the diagram can be printed or exported to PDF using the iText PDF library.

All scanning and grouping actions performed on the cards are stored as history. Thus, participants can review the brainstorming process of a session by specifying a time in the past. The resumption of editing from a previous state is also supported, giving users an undo-like function.

As described above, the GKJ system allows participants to freely choose a proper environment (real or digitized cards) for their tasks, including review of their data using the digitized log rollback and distribution of data. The high level of portability of the GKJ system makes it useful in a variety of environments and scenarios.

6. Practical Application

We operated the GKJ system in small courses of collaborative card-base activities. Figure 14 and Fig. 15 show a class at our institute, while Fig. 16 and Fig. 17 show a lecture course with city hall staff. For the class at our institute, we used pre-printed cards and participants created a radial affinity diagram by positioning the cards spatially to represent their ideas. Participants immediately enjoyed scanning and checking the digitized data. The instructor conducted the course in the same manner as with conventional courses using cards. Figure 14 shows a scene in which the instructor is holding up a card to show it to the participants. This was a significant behavior when using paper cards. Because scan-

Fig. 14 Practice session at JAIST (1).

ning operations were intuitive as compared to creating and placing virtual cards on a PC and checking the scanned results on the GKJ editor was interesting, the instructor often captured the card after moving it.

In the lecture course at a city hall, participants first wrote their ideas and work-related problems on cards. Next, they created a radial affinity diagram by classifying the cards during the discussion. After arranging the cards, participants scanned all card positions.

In both courses, participants acted naturally, as expected. In other words, our system did not detract from the processes they would normally follow. They communicated implicitly by observing the behavior of other participants,

Fig. 15   Practice session at JAIST (2).

Fig. 16   Practice session with city hall staff (1).

Fig. 17   Practice session with city hall staff (2).

Fig. 18   Affinity Diagram at JAIST session.
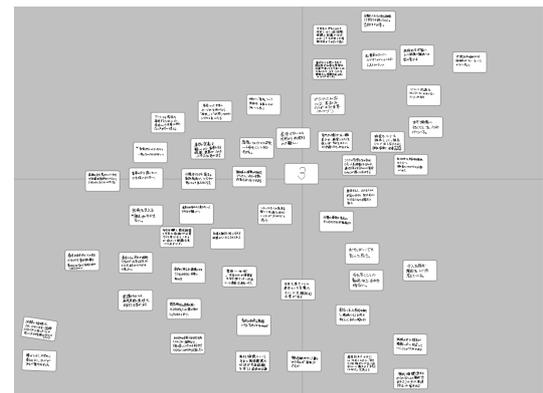
Fig. 19   Radial Affinity Diagram at city hall session.

Advantages

1. Card writing with a pen was straightforward and intuitive.
2. Participants naturally organized their cards because they could observe the behavior of other participants.
3. Quick distribution of digitized logs and figures (PDF) was effective for reviewing the session and garnering further discussion.
4. The instructor and some of the participants mastered the process scanning and enjoyed it.
5. The position of the scanned data accurately represented the physical figures.

Drawbacks

1. Occasionally (10–20% from our observations), the user forgot to preset the scanning area. The GKJ system utilizes four A2-size sheets to compose an A0-sized base sheet. Because the printed-dot pattern of the A2 sheet was the same, the user needed to specify the section of the base sheet to the system before scanning by selecting a check box. To eliminate the likelihood of future occurrences of this mistake, we now prepare four preset pens for each A2-sheet section, and the error rate

such as placing a card on a sheet. After both courses, a PDF file of the digitized diagram (Figs. 18 and 19) was sent to the participants. In a former course, it usually took the instructor several hours to digitize such a diagram for sharing. Furthermore, a precise card-history log was helpful for reviewing the session.

We note the following findings based both on our observation of the sessions and on comments received from the participants.
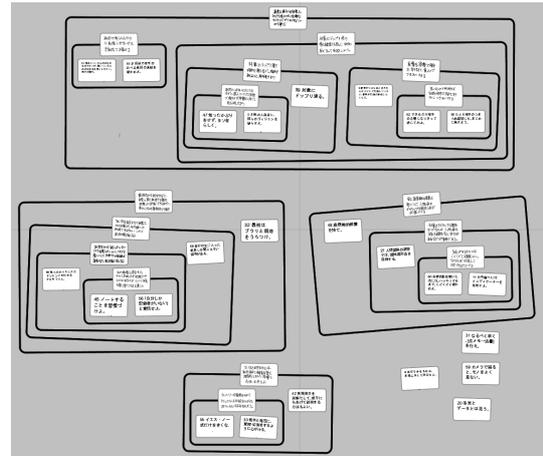
is decreased to 1–5%. Note that if the mistake does happen, the user can easily fix the misrecognition by simply rescanning.

2. Occasionally (5–10% from our observations), extraneous scanning lines appeared on cards and base sheets because of misrecognition during scanning. The misrecognition was caused by weak pen pressure, high scanning speed, and lack of a gap between the cards (less than 1 cm). To solve this issue, we prepared four preset scanning only pens that do not draw extraneous lines. The modification was able to solve the issue perfectly.

3. Some participants (1–5% from our observations) wrote upside-down on the cards because it was difficult to recognize the top and bottom of the cards. This caused card content to also be shown upside-down, and the position was scanned incorrectly. We could address this issue by implementing a function to automatically detect when the wrong side was up by analyzing the handwritten note.

The user needed to understand the characteristics of the pen and GKJ editor software to adequately operate the system; however, this skill could be easily acquired with a few minutes of training and failed scanning could be easily recovered by rescanning. We have refined the GKJ system to eliminate these drawbacks and improved the effectiveness of initial instruction to reduce user mistakes.

7. Experimentation

To clarify the effectiveness of the GKJ system, we conducted a detailed experiment of digitizing a diagram. We hypothesize that the GKJ system can reduce the time taken to prepare a digitized outcome diagram as compared to traditional KJ methods and tools. As part of our experimentation, we also assessed the accuracy of the handwriting recognition engine.

The GKJ system can produce digitized diagram data immediately after scanning. The data is atomic and manipulatable however, the card content still includes handwritten text. We compared the time taken to prepare digitized diagram data with that taken for typed text. The data obtained with typed text is more useful practically than that obtained with handwritten text for reusing contents.

The first experiment was performed during our KJ method summer camp in 2010. The summer camp involved fieldwork to investigate the regional community. We asked eight participants to write their thoughts and impressions of their fieldwork using an Anoto pen. Thirty-five cards were collected in 18 min. Next, they created a radial affinity diagram while discussing their experiences with one another. Finally, the card positions were captured by scanning. The scanning operations (noted as task A-1) were performed collaboratively by four participants, taking a total of 202 s. Card content was converted to typed text using a Japanese handwritten text recognizer [†].

Table 2 Result of handwritten text recognition.

No. of mistyped chars	0	1	2	3	4	5	6–8	9
No. of cards	8	8	11	3	2	2	0	1

The second experiment was performed after the summer camp concluded. We asked six other participants who had not attended the first session to perform the following digitizing tasks:

(A-2) Fix recognition errors in the converted typed text by referring back to the digitized handwritten images.

(B-1) Input text of all cards by referring to the real paper sheet.

(B-2) Arrange the cards by referring to the real paper sheet.

For task B-1, participants utilized the standard Notepad application available in Microsoft Windows. For tasks A-2 and B-2, participants utilized the GKJ system. Card arrangement was performed by simple drag-and-drop operations. We instructed the participants that the task should be completed quickly and accurately. We suggested adding paper clips to distinguish the finished cards in tasks B-1 and B-2.

The affects of learning and fatigue were counterbalanced by changing the order of the tasks. Participants A, C, and E carried out the tasks in the following order: B-1, B-2, and A-2, while the order for the other participants was A-2, B-1, and B-2. The total experiment time was approximately one hour per participant.

7.1 Results of Handwritten Text Recognition

We analyzed the accuracy of the handwriting recognition engine by counting the number of mistyped characters from 35 cards. The original cards contained 26.4 characters on average with a standard deviation of 6.53. The mistyped recognition error was 1.89 characters on average with a standard deviation of 1.86. Table 2 summarizes the numbers of mistyped characters by cards. Most of the mistypes were caused by untidy and incorrect writing.

7.2 Results of Digitizing Cards and Diagrams

To evaluate the effectiveness of digitizing the cards and diagrams, we compared the time taken to finish the digitizing task of A (i.e., scanning and fixing) with that of task B, inputting and arranging the virtual cards. We noted above that the scanning task (A-1) took 202 s. Figure 20 shows results of these digitizing tasks. A paired t-test indicated that task A was significantly faster than task B; more specifically, $t(5) = 3.33$, $p = 0.02$. As a result, our scanning and fixing approach can reduce the digitizing time as compared to conventional methods.

In this experiment, the number of cards is limited. Therefore, the inputting task was easier because the diagram is relatively small and participants could read card contents

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[†] We used a licensed DLL version of InkFepGX by Pothos Corporation, http://www.pothos.to/
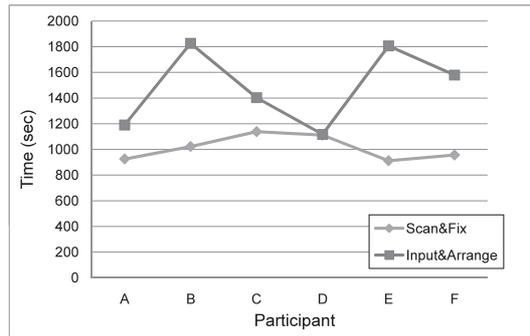
Fig. 20 Time of digitizing tasks, in seconds; A–F denotes participants.

at a glance. Similarly, the arranging task did not take much time. The ability of our scanning and fixing approach will be maximized for digitizing diagrams that contain large number of cards.

8. Conclusion

In this paper, we proposed a method for capturing the location and hierarchical structure of paper cards written with Anoto pens. Our method enables participants to record a precise atomic transition log of the cards. We also developed our GKJ system for digitizing paper-based card organization tasks instantly. Due to the simplicity of the pen-based input, the GKJ system is universal.

We confirmed the effectiveness of our system by applying it during several sessions, including a small-group learning session of 10 participants. Our system is applicable to a variety of participants and groups because it can handle up to 42 pens simultaneously. For future work, we plan to refine the GKJ system to improve its usability and further increasing its applicability to a wide variety of meetings including town meetings.

Acknowledgements

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