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Research article

Design discussion support system with graphical mapping

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Abstract

This study addresses the development and evaluation of a group discussion support system in design planning and discussion stages. Creation of design plans generally involves research and evaluation of design plans by trial and error through discussion by participants of diverse specialty and knowledge. Graphical mapping methods such as Mind Map and idea creation with cards are effective in the process of embodying ideas gradually while consulting many idea resources. However, these graphical techniques are not fully supported in a digital environment. We have developed a process model of group discussion, prototyped a Web-based design discussion support system, and examined its feature and the benefits of systematization of the graphical mapping method. This article describes the result.

Keywords: design discussion support, system development, graphical mapping, collaboration

Introduction

In the initial planning stages of architecture, interior design, and district facilities, many idea groups expressed by sketches or keywords are extracted through trial and error. Design solutions are pursued step-by-step through examination and evaluation of design plan feasibility. These processes are regarded as creative processes of

consensus-building not only by professional engineers but also by many non-experts such as clients, organization staff members, students, and residents.

Workshops and group discussion are regarded as effective methods for consensus building with participation and discussion processes shared among many people. Related preceding studies include a city planning study that examines problem-finding discussion in a workshop with residents' participation[1] and a meeting study that adopts the group idea creation technique[2]. These studies generally adopt graphical expressions in which participants describe free ideas and associative images on sticky notes or cards, which are then rearranged or grouped. This technique, which "visualizes" the relation among idea groups to encourage creative ideas by group discussion, has spread broadly not only in the design field, but also in the business field as graphic facilitation (GF).

Research Background and Objectives

Processes to create ideas through discussion and to merge them as a final design plan comprise two stages: an "idea divergence stage" and an "idea convergence stage." An "idea divergence stage" is one in which images and keywords are extracted from discussion participants, who share ideas stimulating findings and mutual inspiration unobtainable from individual thinking, whereas points of argument are organized by graphical expression (visualization) in an "idea convergence stage," in which the extracted ideas are compared, regrouped according to relevance, and organized with their benefits or shortcomings examined. Processes in a workshop, which include writing comments and ideas on cards or sticky notes and preparation of graphical mapping on a white board or simili paper as described above, include the following problems.

- Insufficient adoption and systematization of group discussion methods adapted to "visualization" such as graphical expression and mapping.
- Complicated processing of recording a series of processes toward consensus building through discussion and reference to it as a history.

To date, our research group has developed a group discussion support system that is equipped with a pinup-board type interface. This system has realized operability that allows a user to lay out the thumbnail images of digitally recorded idea sketches and keywords to resemble a pinup board, but its function, which is support of the introduction of graphical methods and idea structuralization, is insufficient. We consider that facilitation function by graphical expression of the contents of discussion (= "visualization") is necessary for efficient collaboration through group discussion. Accordingly, this study aims at the development and functional evaluation of a group discussion support system, Architectural Proposal Exchanging/Visual Pinup Board (APEX/VPB v2), equipped with the GF method. Our methods of research include an experiment to verify discussion using graphical mapping and selection of a GF technique suitable for design discussion. We then conduct a functional comparison and evaluation of existing graphical mapping tools and preparation of the process model of "idea divergence" and "idea convergence" stages, and constructed a prototype system. Finally, we elucidate the effectiveness of a discussion support model using a system introduction experiment and questionnaire evaluation.

Characteristics and Effectiveness of Graphical Mapping Discussion

A graphical mapping discussion using the GF is a technique that presents participants' comments and points of argument graphically, aiming at efficient discussion conducted in a short time. This technique is comprehensible to non-experts and provides a stable framework for complicated and often uncontrollable group discussion processes. Therefore, it is expected to encourage voluntary participation and mutual inspiration of discussion participants. Its characteristics and effects are the following.

- Comprehensive view of the whole discussion allows participants to identify problems and to improve the concentration and quality of discussion.
- Preparation and proposal of figures or images encourages the active involvement of participants.
- Sharing images prevents divergence of the discussion or excursion of points of argument.
- Mutual inspiration to develop a novel idea from others' viewpoints or ideas.
- The consensus building process can be recorded and saved by understanding the evolution of ideas.

Discussion experiments were conducted to verify the benefits of the described above GF. Graphical mapping methods of three types were adopted for idea creation: Mind Map, Mandal-Art, and Ajatuskartta (Finnish style Mind Map). Table 1 presents characteristics of the graphical mapping methods.

Table 1 Characteristics of graphical mapping methods used for discussion experiments

Method	Technique	Characteristics
Mind Map (Hierarchical tree)	Graphical diffusion and divergence by figures and characters, and colors and sketches.	Visual and comprehensible, but illustration skill required.
Mandal-Art (Fractal structure)	Semi-structuralized graphical expression in which a 3 × 3 grid is filled with keywords, and multiple keywords are extracted from the subject.	Keyword-based and easy to practice. Preventing escape or thinking bias by designating an entry position with a grid.
Ajatuskartta (Framework free association)	Associative graphical mapping method with logical analysis/subdivision within a 5W1H framework.	Logical compatibility that is explicable based on six points is regarded as important.

Participants of the discussion experiments, 8 undergraduate and 27 graduate students, were subjected to a choice and descriptive questionnaire and a five-grade functional evaluation after idea discussion exercise. Table 2 presents some key points of the result (evaluated by average; full mark is 5).

Table 2 Partial results of questionnaire use of graphical mapping methods

Graphical expression method and evaluation stage	Evaluation criteria	Points
Mind Map Divergence/extraction stage	Keywords to be reminded are conceived immediately.	3.5
	Branches can be drawn stretched unrestrictedly.	4.2
	Would like to express also with illustrations or photographs.	3.4
Mind Map Convergence/organization stage	Flow and whole of discussion process are expressed well.	2.9
	Suitable for group discussion.	4.2
Mandal-Art Divergence/extraction stage	Sufficient grids and positioning for putting keywords.	3.7
	Would like to express also with illustrations or photographs.	3.3
	Ideas are examined without oversight or escape.	2.3
Mandal-Art Convergence/organization stage	Whole discussion process is expressed well.	3.3
	Suitable for group discussion.	4
Ajatuskartta Divergence/extraction stage	Smoothly connected with keywords.	3.3
	Logical idea created by virtue of 5W1H framework.	3.6
	Would like to express also with illustrations or photographs.	3.8
Ajatuskartta Convergence/organization stage	Flow and whole of discussion process are expressed well.	3.4
	Suitable for group discussion.	3.7

The questionnaire result revealed the benefits of graphical mapping methods as follows: 1) recording using figures and images encourages idea creation and conversation in a group; 2) thinking bias is mitigated and idea extraction from diverse viewpoints is implemented; and 3) graphical expression methods facilitate combination (association) and convergence of ideas. Presumably, the graphical mapping method by the GF is effective in group work in the planning stage where design plans are researched, and "visualization" by graphical expression is useful for creative idea generation. However, the following problems arise: 1) graphical mapping by the GF might hinder free thinking depending on themes; 2) once written down, correction, revision, and figure relocation are difficult; 3) difficult to organize and comprehend relevance with increase in idea groups; and 4) difficult to archive and share (distribute) maps as an accomplishment of discussion. These problems arise because work with analog tools such as paper and markers is too complicated for edition of idea groups or structuralization (arrangement) of association in design discussion that progresses through trial and error. Accordingly, this problem is regarded as solvable through digital support for discussion as examined in this study.

Discussion Process Model of Design Idea Creation Step

Relations among idea groups are organized and restructured using grouping by graphical expression, with reference to idea resource groups. Discussion processes with an idea structuralization stage were modeled to systematize this work (Fig. 1). Figure 1 shows workflow with a three-stage model of divergence, structuralization, and convergence in the proposed idea discussion work. This discussion process model organizes idea group relations through preparation of graphical mapping using the GF method from the stage of extraction and sharing most possible ideas and images. The model prepares and submits proposals engendering design solutions in the convergence stage.

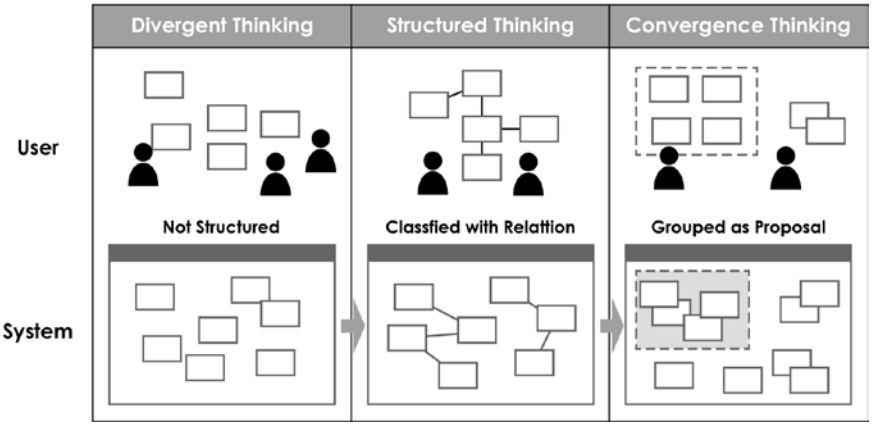

Fig. 1 Three-stage discussion model of divergence, structuralization, and convergence.

Idea reference and arrangement techniques by graphical mapping include a multi-axis diagram depicting tree (hierarchical), matrix, chronological, and map methods. Three pinup board interfaces corresponding to a multi-axis diagram with a matrix and a map tree type of a semi-lattice structure were mounted in the structuralization stage proposed in this study.

○ **Normal PB (normal pinup board)**

Resource icons are arranged on a web browser, with list display and editing of registered resources conducted for free image extraction in an idea divergence stage.

○ **Classify PB (classification/arrangement pinup board)**

Design resources are classified and categorized into a matrix table of four quadrants. Those increasing with discussion are organized according to importance or category.

○ **Relation PB (association pinup board)**

Map display of a semi-lattice structure is conducted. Thumbnail icons representing each idea are connected with links of a variable length. The relevance of design plans is displayed graphically for proposal preparation in the structuralization and convergence stages.

Idea discussion work is supported seamlessly by making these three pinup boards switchable at any time in a discussion process. Figure 2 presents the interface of the pinup boards described above, corresponding to graphical mapping by the GF.

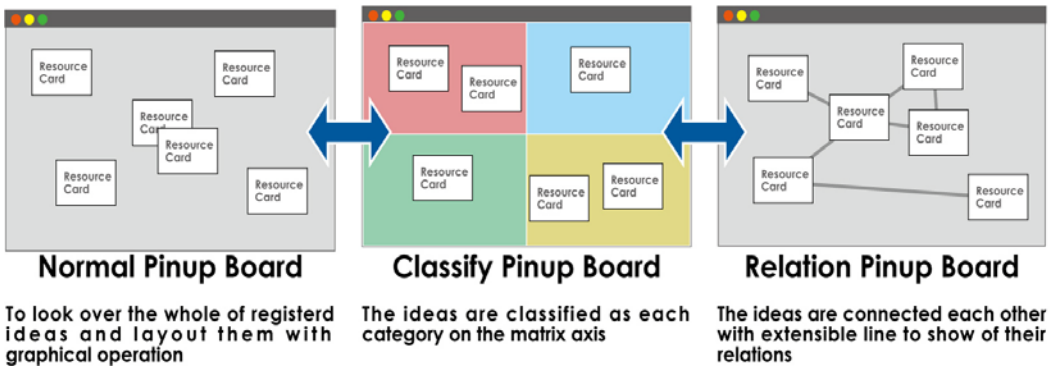

Fig. 2 Pinup boards corresponding to divergence, structuralization, and convergence stages.

"Individual work" in which a discussion participant performs idea preparation independently, and "group work" in which multiple participants share sketches and keywords during discussion were observed alternately in the previously described discussion experiment. Accordingly, work is defined for contemplating and embodying ideas as Personal mode; work for examining the pros and cons of ideas in a group as Public mode. Furthermore, a pinup board on which all the idea resources in the divergence stage are listed is defined as the Resource PB. A pinup board on which idea resources are associated and coordinated is Proposal PB. A discussion participant presents an idea prepared in Personal mode to Public mode for browsing and evaluation by other participants in a group (Fig. 3).

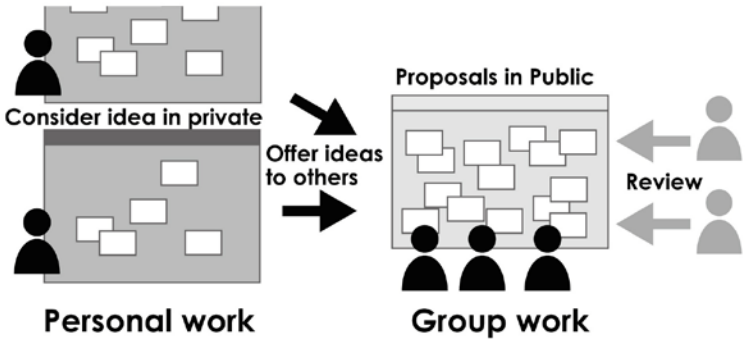

Fig. 3 Process from Personal mode to Public mode.

Ideas are extended in design discussion work that shifts over four stages of work phases in the four quadrants in Fig. 4 combined by "Resource PB – Proposal PB" and "Personal mode – Public mode."

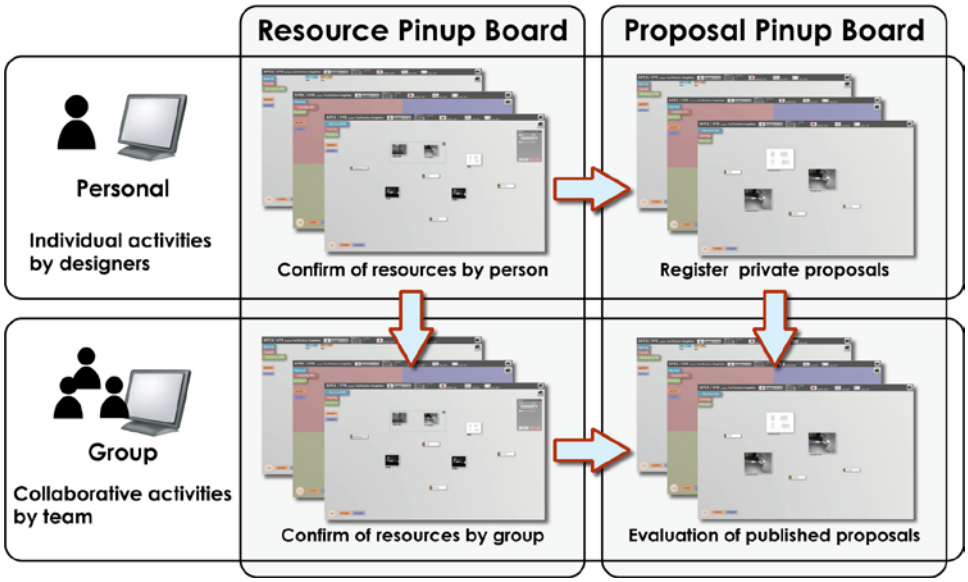

Fig. 4 Four phases of design discussion work.

Outline and roles of the four phases are the following.

○ **Personal mode + Resource PB**

Browsing, search, and structuralization by individual work of resources registered individually. An idea resource is not opened to others, in principle.

○ **Public mode + Resource PB**

Browsing, search and structuralization by group work of open resources, and proposal preparation.

○ **Personal mode + Proposal PB**

Registration, browsing, and preparation of disclosure of proposals in individual work.

○ **Public mode + Proposal PB**

Browsing and evaluation of proposals by group work, such as comments and discussion to a presented proposal.

Ideas and evaluation thereof are structuralized by the GF and are arranged in each stage.

We assume that an image and a keyword are the minimum units of creative thinking. We consider that design thinking can be recorded and expressed using comprehensive patterns from a viewpoint over all contents of discussion in this study.

Development of Discussion Interface Corresponding to Graphical Mapping

VPBv2 with graphical mapping function added was developed based on a Visual Pinup Board (VPB), which offers discussion support by operation similar to an existing pinup board. APEX/VPBv2 consists of Adobe Flash® on the

client side and a relational DB by PHP and MySQL on the server side. Figure 5 shows the system outline of APEX in charge of registration and accumulation of ideas and VPB, which can refer graphically to idea resources.

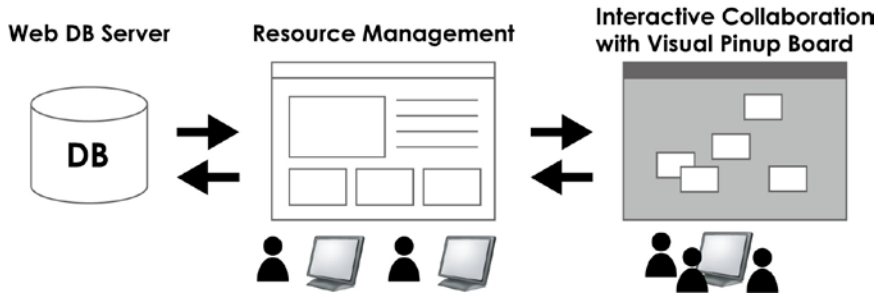

Fig. 5 System configuration and flow of APEX/VPB.

Configuration and Basic Operation of APEX/VPB Interface

The basic screen configuration and role of APEX/VPBv2 is described. A discussion participant registers images and texts as design resources into a library beforehand and shares them on the "Resource PB." A pinup board for displaying idea resources displays the thumbnail icons and keywords of idea sketches as a text on a sticky note. They can be displayed as a free layout, and can be refined with searching by user attributes; chronological ordering can be performed (Fig. 6).

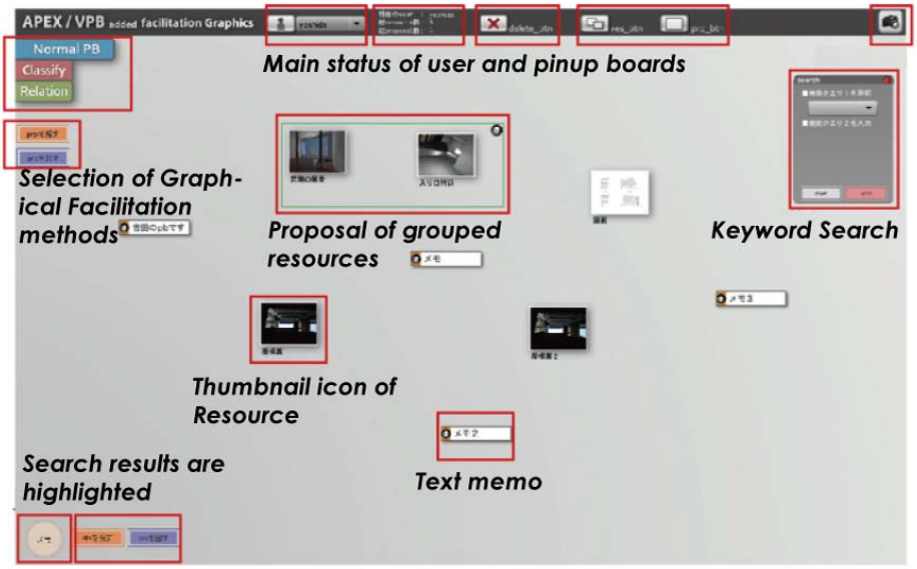

Fig. 6 Basic screen of the Resource PB for registering and consulting ideas.

A participant prepares and saves a proposal plan through resource browsing, comment entry, and grouping of multiple resources (Fig. 7).

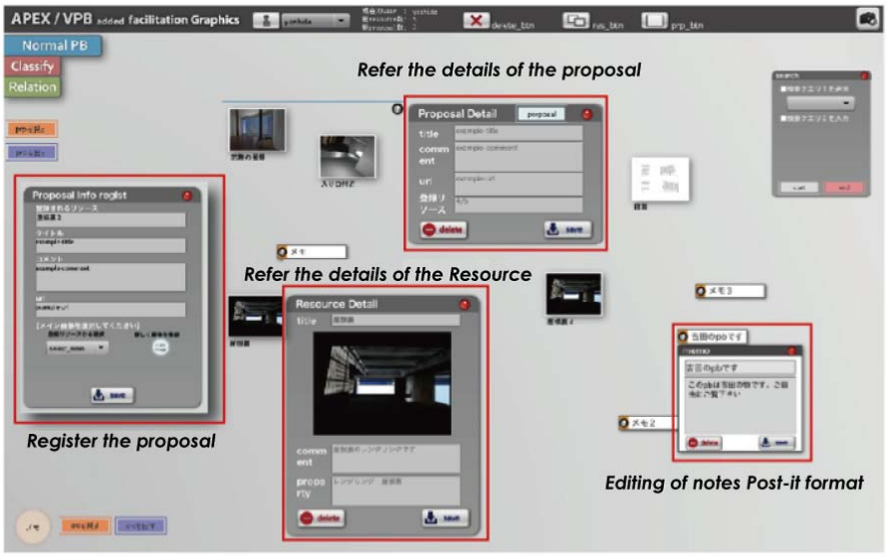

Fig. 7 Registration and editing subwindows on Resource PB.

Resources can be manipulated and narrowed with attributes (registrant, date, keywords, etc.). Their arbitrary ensemble is edited as a proposal (Fig. 8).

Fig. 8 Search and display by Resource PB

Resources are organized by an individual or a group with respect to a category or importance on a matrix pinup board. The matrix expression can set up the attributes of four quadrants. It lays out registered resources and proposals on a pinup board and categorizes them similarly to SWOT analysis (Fig. 9).

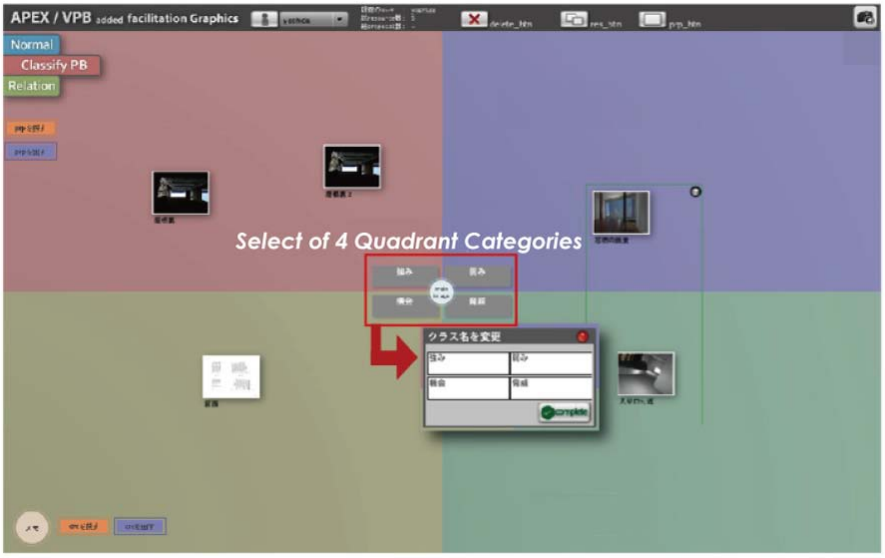

Fig. 9 Idea arrangement by four quadrant matrix

Relevant resources and proposals are connected with links of variable length. The relation of ideas is presented visually using a network semi-lattice structure, so that they are structuralized hierarchically on a pinup board of relation display (Fig. 10).

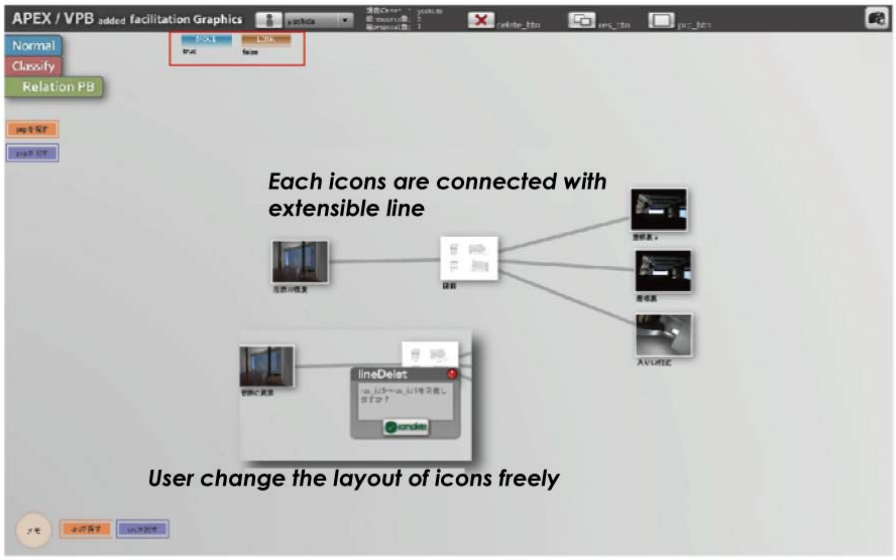

Fig. 10 Relation display that allows link display.

In a convergence stage after discussion by an individual/group and a structuralization stage, design proposals are shared by and disclosed to discussion participants as a proposal. The contents of each proposal can be spread on a submap by a click (Fig. 11).

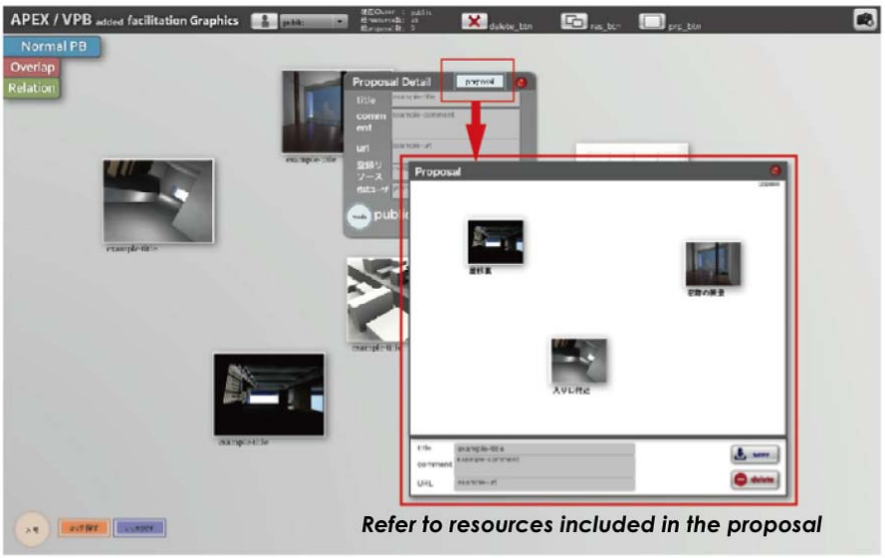

Fig. 11 Browsing and evaluation of published proposal

Functional Evaluation of Discussion Interface corresponding to Graphical Mapping

Participant experiments were conducted to evaluate the operability and function of APEX/VPBv2 with graphical mapping added. Participants received simple lectures about the basic operation and application concept of APEX/VPBv2. Then they performed individual work independently with a PC-terminal and group work in an environment of a projector + mouse + electronic pencils + keyboards. Table 3 presents the task flow and experiment flow used for system evaluation.

Table 3 Tasks and workflow of functional evaluation

Stage	Task
Lecture	Explanation of experiment objective Handout and lecture on operations
Individual work experiment (work with single PC monitor + mouse + keyboard)	Collect about 10 images per person via the internet. Open an account on the system and upload the images. Open own Resource PB from "open VPB" menu, and enter a title comment into the resource. Organize resources using the GF function, search service, and sticky label memorandum function. Register a proposal. Open a Proposal PB and confirm the contents. Switch a proposal to release to "Public mode." Browse PB of other participants.
Group work experiment (works with a projector + mouse + electronic pencils + keyboards)	Confirm resource proposals registered by members on Public mode. Organize resources using the GF function, search service, and sticky label memorandum function. Register and consult a proposal.
Questionnaire hearing	Questionnaire entry (3P task analysis)

Hearing (group interview)

The questionnaire and hearing were conducted on operability, design performance, and understanding of functional concepts for each task. Figure 12 presents results.

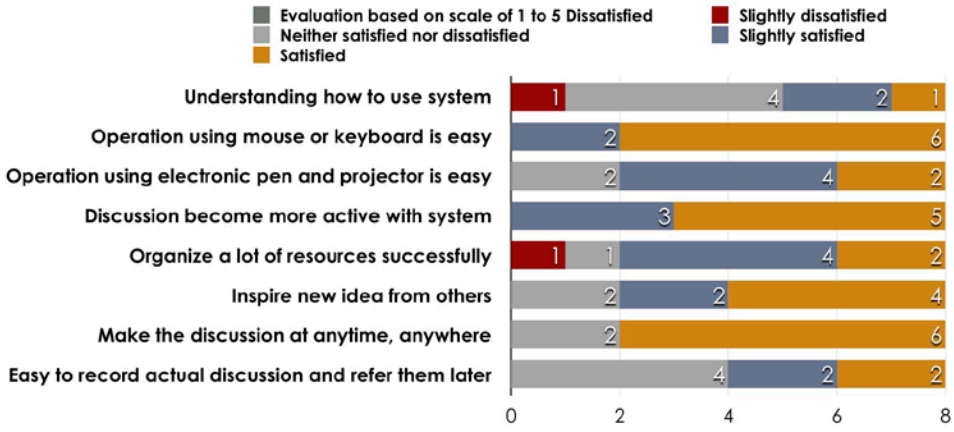

Fig. 12 Partial results of questionnaire survey administered after the experiment.

Comparative Discussion Experiment by Digitized Graphical Mapping Method

Next, to verify the effectiveness of idea discussion support by the APEX/VPBv2 system environment, group discussion experiments using the conventional method with white board writing and card entry and the digital graphical mapping method by APEX/VPBv2 were conducted. The results were compared. Table 4 presents the procedure and time divisions of the experiments.

Table 4 Outline and timetable of idea discussion experiments

Item	Contents	
Participant	9 students of the Faculty of Design Information (3 teams)	
Time	Discussion experiment; 40 min × 2 times	
Theme	"Ideas to gather people into the Burakuri-cho shopping street in Wakayama-shi"	
Executed programs		
Stage	Time	Work contents
Preparation	beforehand	Idea creation, image collection
■Experiment in the conventional environment		
Divergence	10 min	Confirm ideas and attach comments
Structuralization	15 min	Structurize idea groups with two-axis, chart, mandala, etc.
Convergence	10 min	Idea grouping and proposal preparation
Sharing	5 min	Presentation and reflection on discussion
■Experiment in system-aided environment (face-to-face use, distributed use)		
Divergence	10 min	Confirm ideas and attach comments and tags
Structuralization	15 min	Structurize by GF board and search service
Convergence	10 min	Proposal preparation
Sharing	5 min	Presentation and Reflection on discussion

A work task of the functional evaluation of discussion methods and system using environment on a discussion theme of idea creation for revitalization of a town is compared on three stages of divergence, structuralization, and convergence stages of a design plan.

Fig. 13 Discussion scene using a conventional method (left) and the system-aided environment (right).

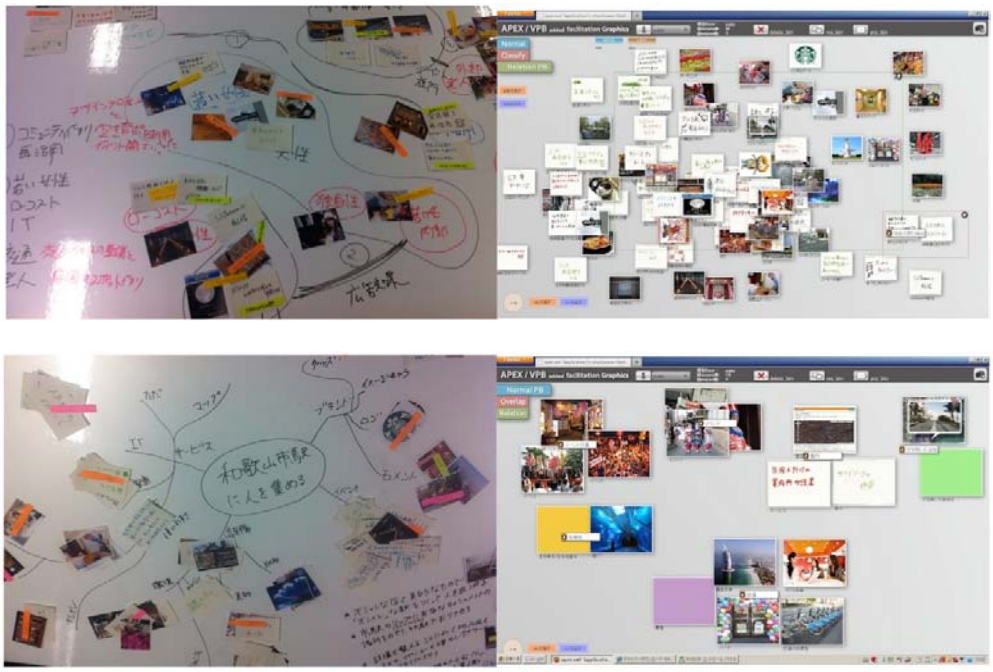

Fig. 14 Conventional environment (left), environment aided by face-to-face and distributed utilization system (right).

Opinion collection by questionnaire and hearing and point evaluation (5 grades) on operability were conducted after the experiment. These results were divided into divergence, structuralization, and convergence stages, and were described.

○ **Evaluation of discussion work and system function in divergence stage**

Here are the descriptive answers of four items and the hearing result as the evaluation of work in an idea divergence stage; Fig. 15 shows the obtained evaluation point.

Divergence – 1: "Easy to conceive a good idea."

- Conventional environment: New ideas occur only slightly because of a lack of information. Thinking only within own knowledge.
- System-aided environment: An idea can be created as inspired by images on the network. Others' ideas are informative.

Divergence – 2: "Many ideas can be created and collected."

- Conventional environment: Fast work by handwriting. Basic knowledge (of graphical expression) is required.
- System-aided environment: Easy to collect images from the network. Easier management than when using paper.

Divergence – 3: "Easy to express and arrange conceived idea."

- Conventional environment: Easy to make notations. Difficult to express with pictures. Work space required.
- System-aided environment: Similar images can be searched. Limited modes of expression.

Divergence – 4: "Easy to attach comments and keywords to ideas."

- Conventional environment: Two or more people can work simultaneously. Writing space on a sticky label is limited. Easy to rearrange.
- System-aided environment: Much information can be written in. Tiresome sticky label memo writing and typing. Two or more people cannot work simultaneously.

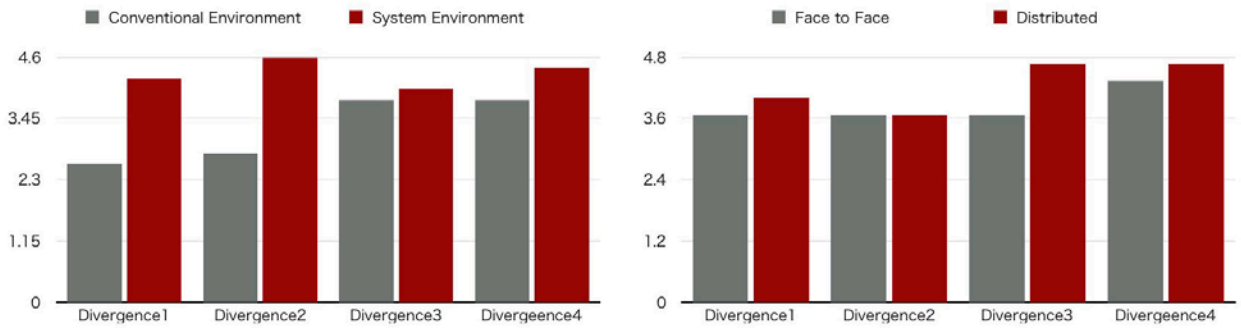

Fig. 15 Comparison of conventional and system-aided environment in divergence stage (individual work).

○ **Evaluation of discussion work and system function in the structuralization stage**

Here are the descriptive answers of four items and the hearing result as the evaluation of work in an idea structuralization stage; Fig. 16 shows the obtained evaluation point.

Structuralization – 1: "Many ideas can be organized quickly and easily (no complicated work)."

- Conventional environment: Broad space required. Complicated at an increased number of cards. Tools such as paper and pens required.
- System-aided environment: Need to get used. Only one sheet can be worked at a time. Many ideas can be listed. Contents are understandable using added information.

Structuralization – 2: "Organizable in satisfactory way (no inconvenience)."

- Conventional environment: Modification and relocation are troublesome in a late stage of work. Troublesome work to move one card at a time. Risk of losing cards.
- System-aided environment: Simple grouping operation. Stylized arrangement is easy to understand. Too many ideas are difficult to work with.

Structuralization – 3: "Easy to examine and organize ideas from various viewpoints."

- Conventional environment: Uncorrectable after finishing structuralization. Space required for revision.
- System-aided environment: can be discussed from various viewpoints. Can be expressed in various modes. Easy to organize. Limited procedures.

Structuralization – 4: "Easy to search for a specific idea. Easy to comprehend what is where."

- Conventional environment: Difficult to find from increased overlapping ideas. Whereabouts unknown. Easy to find pictures.
- System-aided environment: Findable by search. Easily viewable list screen. Details are unclear on a small display.

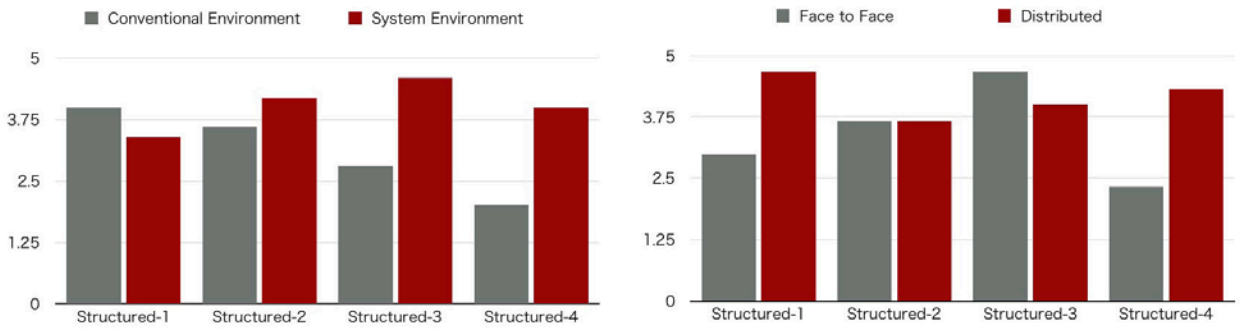

Fig. 16 Comparison of conventional and system-aided environment in the structuralization stage.

Although the system-aided environment surpassed the conventional environment a little, the face-to-face environment in which card and map entry can be performed in conversation is easy to understand intuitively. It was evaluated that the distribution of ideas are easily understandable because of individual work in the distributed environment, although idea arrangement without conversation is slightly complicated.

○ **Evaluation of discussion work and system function in convergence stage**

Here are descriptive answers of three items and the hearing result as the evaluation of work in an idea convergence stage; Fig. 17 shows the obtained evaluation point.

Convergence – 1: "Convergence work by reference to preceding discussion."

- Conventional environment: Convergence work dependent on people. Cannot keep up unless comprehending the discussion flow. High degree of freedom.

- System-aided environment: Convergence work with switching boards. Grouping only by encircling. Organized state observable at any time.

Convergence – 2: "Easy to make a proposal (registration procedure not complicated)."

- Conventional environment: Cannot move freely. Increased ambiguity by adding lines.

- System-aided environment: Converge with exclusion of superfluous objects. Comfortable grouping.

Convergence – 3: "Easy work in a team without complications."

- Conventional environment: All members can work simultaneously. Complication in concurrent job.

- System-aided environment: operator limited. Work suspended by menu manipulation. Tend to stand aside.

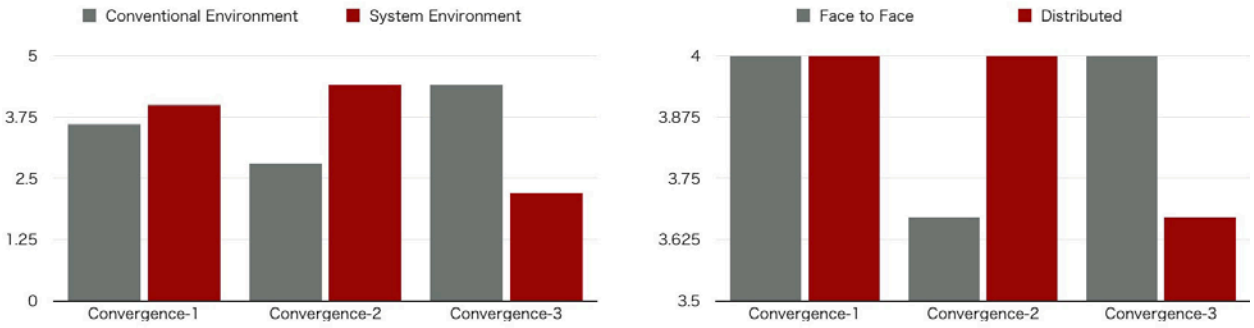

Fig. 17 Comparison of conventional and system-aided environment in the convergence stage (group work).

Conclusion of this Study and Discussion

Results of this functional evaluation of the system and discussion experiments have revealed the following benefits of the APEX/VPB discussion support system proposed and developed in this study.

■ Benefits of the APEX/VPB interface

Facilitated discussion from plural views by switching PBs.

Organized work screen and low likelihood of becoming complicated as discussion progresses.

No temporospatial restriction. Easy recording and sharing.

It is evaluated highly for structuralization work for face-to-face use, and for information gathering / convergence work for distributed use.

The APEX/VPB interface corresponding to graphical mapping can mitigate work such as preparation and arrangement of sketches and notes in a design initial stage for idea planning by digitization. It enables collective management of idea resource groups that increase as discussion work progresses. Consequently, graphical mapping is regarded as effective in perspective understanding of idea resource groups and creative activity by group work. Furthermore, a three-stage process model of divergence–structuralization–convergence proposed in this study has steadily acquired evaluation as a framework of system construction. However, some issues were revealed.

■ Issues related to the APEX/VPB interface

Improvement in operability and interface according to the conventional method.

Mounting of a graphical expression method that can perform subtle idea arrangement

Improvement in communication support in asynchronous work

The dominant causes thereof are presumed to be that the menu as a web interface and design of command positioning are insufficient, the workspace is limited to the displayable region of a device, and the graphical mapping introduced this time is not sufficient for design discussion that mainly handles figures and images. The model and system development of the graphical expression idea creation method must be improved in the future.

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