A Design of Web-based GDSS that Supports Anonymous Communication and the Convergent Process

Atsushi Iwai and Kazuhiro Sado

***Abstract*— Most of the successful supporting frameworks of anonymous communication in group decision support systems (GDSS) are designed for the divergence phase in a decision process. Not many GDSS designs address the later convergence phase where participants through discussion seek a conclusion or an answer. This paper presents a new design for a Web-based GDSS that supports anonymous communication for the convergent process. We also illustrate an implementation of a prototype system and offer an evaluation using a decision making experiment of document selection.**

Index Terms—Web-based GDSS, Convergent Process, Anonymity, Communication System, Document Selection.

I. Introduction

Supporting anonymous communication to improve group decision making is a longstanding concern to researchers of group decision support systems (GDSSs). As some real world social relationships in decision-making groups are considered detrimental to the quality of communications in decision making processes, it can be expected that removing the ability for group members to exert strong social influences on other members should improve the quality of final decisions.

Most of the successful supporting frameworks of anonymous communication in GDSS are, however, designed for the divergence phase in a decision process, where participants look for options or new ideas. To give a simple example, as is widely known, electronic brainstorming allows members to enter their ideas at will while providing anonymity to the author of an idea. This method not only reduces the effects of production blocking but also reduces evaluation apprehension on group performance by introducing an anonymous communication infrastructure.

In the convergence phase that follows, where participants discuss and seek a conclusion or an answer, not many designs with frameworks for supporting anonymous communication have been presented. It seems to be assumed that anonymity may remove some tools of persuasion, and increases the difficulty of coordinating discussion. The benefits of supporting anonymous communication are to some extent dependent on the system design. But, the difficulty of establishing an anonymous communication framework for the convergence phase is especially true for many of the present day GDSSs that are often web-based and with the participation of more distributed users.

This paper presents a new design for a Web-based GDSS that supports anonymous communication for the convergent process. We develop the design by improving a conceptual framework presented in previous studies, and give a formal description. We also implement a prototype system and evaluate it by a decision making experiment of document selection. As suitable candidates to benefit from the method, this study focuses on organizations whose population ranges from tens to hundreds. They are expected to be organizations such as corporations or schools in the real world that have clear borders to separate members of the organization and outsiders.

The structure of this paper is as follows: the second section sets out the problem that needs to be solved and illustrates the framework of past studies. The third section explains the basic design approach and its formalization. The fourth section proposes implementation of the supporting system and its evaluation. The third section is mainly written by Iwai; the first part of the fourth section mainly by Sado; and the rest of the fourth section mainly by Iwai.

II. Problem and previous framework

A. Problem Specification

We chose the following book selection example that involves hundreds of university students as a typical problem that needs to be solved.

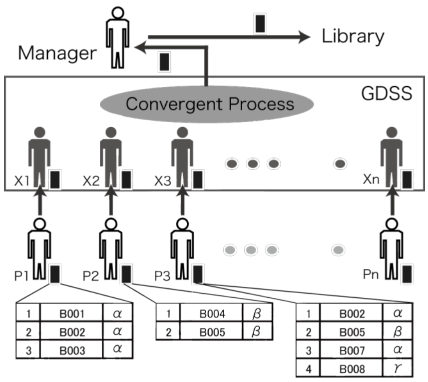

Fig. 1. Problem Specification

<Problem Scenario>

A lecturer in a university is obliged to recommend new reference books to the university library for the students of a department. There is a maximum limit to the total number of

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recommendations; in addition, only books of three categories, alpha, beta and gamma can be recommended. All competing categories in the scrabble to obtain budgets have to be balanced in some way. Now, the lecturer wishes to ask students to use a GDSS and make a recommendation list to be used as a reference before giving the final book recommendation list to the library.

Fig.1 is the illustration of the problem. P1, P2, …, Pn are the participants. Each participant uses a unique and unchangeable handlename (X1, X2, ..., Xn) to communicate with others in the system (This guarantees anonymity). A participant may have a list of books for recommendation. The order in the list indicates the preference of the user. For an example, P1 has a book titled B001 of category alpha as the first item. A user may have a list that consists of books of a single category like P1 and P2, while lists of some other participants like P3 may consist of books of multiple categories.

Our target is to establish a GDSS where students in the problem above can discuss their candidate books using a supporting framework of anonymous communication and then make a decision. As a result of opinion convergence, one conclusion list is to be derived and submitted to the manager as a reference before compiling the final list to submit to the library.

There are two types of conditions in the decision making. One has a specific configuration description and the system can support users with automatic calculation, e.g. limitation of the total budget. Another type of condition does not have a specific configuration description, e.g. the balance of the three categories. To some extent the definition of this type of condition depends on the participants; participants would need more persuasion and coordinated discussion in a convergent process. Actually, many real decision processes have both condition types and it is reasonable to include them in the problem.

B. Related Studies

Here, we illustrate a GDSS design for the convergent phase presented in previous studies ([3][4]). It supports anonymous communication but is not an ideal solution to the above problem. It did not propose the replacement of the existing conventional committee in charge of decision making by online GDSS, but rather the setting up of GDSS beneath the present committee with the right to submit agendas up to the committee; the aim being the overall strengthening of the decision system. Participants are known as citizens and the system is called an online assembly.

The framework of establishing the system was proposed as 23 rules of natural language. The design part that will enable the gathering of minds and focusing of discussion for convergent discussion is as follows: the aim is not to create one enormous assembly in which all citizens participate, but rather a more stratified, autonomously organized system. Members of the public with opinions on a particular issue would first of all call for others able to meet regularly at a particular time. This would result in the autonomous creation of a number of small assemblies.

For simplicity, the descriptions of the 23 rules are omitted. We use a debating scenario for illustrating important aspects of the system design.

The table below is an example of a debating scenario from an online assembly, showing the application of the rules. Fig. 2 is a diagrammatic representation of this scenario. For the purpose of simplicity, this scenario assumes a total of sixty eligible voters and a limit of ten people in each assembly. When any particular result carries a weight of 20% of all voters, in this case 12, it is submitted to the conventional decision making committee.

Table 1. A Debating Scenario

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A1	◎	○	○	×														
A2		◎	○	○	○	×	×											
A3				◎	○			○	×	×	△							
A4		◎	○	◎	○			○										
A5		5				−2	″+		−2			○						
A6	◎				○							○	○	○	×			
A7	5	7				−3				!+						○	○	○

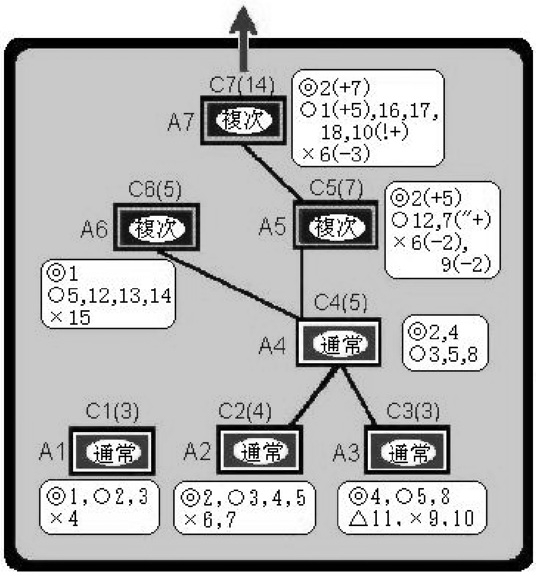

Fig. 2. An Illustration of Debating Scenario([3])

Each row of the table corresponds to the convening of one assembly. A1 to A7 are online assemblies, of which A1 to A4 are ordinary assemblies (including those voting for combined proposals), and A5 to A7 secondary assemblies convened to discuss the pros and cons of conclusions reached by other assemblies. Each line shows the result of voting at each assembly. Each figure in the top line represents an eligible voter and these participants are labeled P1, P2...etc. In the table and in Fig. 2, a single circle denotes a yes vote, and an X a no vote (in the case of votes cast by representatives in a secondary assembly, the total of supporting and opposing votes are shown with a + and - respectively). A triangle signifies an abstention. A double circle is used to indicate the person who called the assembly (this has been abbreviated for A5 and A7 because of space restrictions). The " and ! represent votes in a secondary assembly and are used when a participant casts a vote contrary to the opinions they expressed in the past. The " symbol is used when the person actually took part in the secondary assembly, and the ! when they did not. A + is added to indicate a change from an

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opposing to a supporting vote, a – is added for a change from a supporting to an opposing vote. C1 to C7 in the diagram represent conclusions reached by A1 to A7 respectively, with the weight of the votes in parentheses. The lines joining the assemblies in the diagram show the origins of the assembly results.

The following is an explanation of the debates in A1 to A5.

[A1] P1 calls for a debate on subject S1, and P2, P3 and P4 respond. The three participants apart from P4 vote in support, and C1 with a weight of 3 is registered as the result for A1. P1 was chosen as the LS (Leader of Supporters), however the opposing faction declined to choose an LO (Leader of Opponents). (supporting -opposing)...(3-1)

[A2] P2 calls for a debate on subject S2, and P3, P4, P5, P6 and P7 respond. All cast supporting votes apart from P6 and P7, and C2 with a weight of 4 is registered as the result of A2. P2 was chosen as the LS, and P6 as LO. (4-2)

[A3] P4 calls for a debate on subject S3, and P5, P8, P9, P10 and P11 respond. P11 abstains from the vote, P9 and P10 vote in opposition, and the remaining three votes in support. C3 with a weight of 3 is registered as the result of A3. P4 became the LS, and P9 the LO. (3-2)

[A4] The similarity between C2 and C3 leads to consultation between representatives P2 and P4, who decide on a proposal which combines the conclusions reached by their respective assemblies, and call a meeting to obtain approval for this proposal. The five participants who voted in support of C2 and C3 agree to the proposal, which is then registered as C4 "an assembly result of C2 and C3 with a weighting of 5," and P2 chosen as the LS. (5-0)

[A5] P2 as LS calls a secondary assembly to increase the weight of C4, P6 and P9, the LOs of C2 and C3 take part, as do P7 and P12. P2 casts their five supporting votes, P6 and P9 their two opposing votes each, and P7 and P12 a supporting vote each (P7 has a change of opinion). Of the two opposing votes held by P6, because one was an opposing vote cast by P7 in the past, it is deducted from the total, giving a final result of seven in support, and three in opposition. A new result C5 is registered with a weight of 7 (with the same contents as C4), and P2 again chosen as LS and P6 as LO. (7-3)

(The descriptions of [A6] and [A7] are omitted.)

Here, persuasion and coordinating discussion are enhanced by the system design in which each participant needs to accumulate votes for realization of their plan. The system framework to support anonymous communication that utilizes unique and unchangeable handlenames enables overlapping votes to be removed automatically from the system. Participants are able to change judgments they have made in the past via the secondary assembly voting process as this framework guarantees the recording of the origins of all votes held by representatives, and prevents duplication.

The drawbacks of the framework for supporting convergence in the previous studies are as follows:

x) The process for making a joint opinion is not clearly defined. In A4, the process of deriving C4 from C2 and C3 is vague.

y) Every time participants make a joint opinion, a new vote is needed. In A4, the initial vote count of C4 is zero. This virtually means the vote counts of C2 and C3 are initialized. This problem of inefficiency also appears every time a participant makes an arrangement to a previously presented opinion.

The framework may be adequately used in such examples as a local government system for collecting residents' opinions, where altering or jointing opinions are rather rare. However, in a meeting to decide a budget plan as in the scenario above many convergent processes would be full of new alternatives with small arrangements. This is an important aspect to be supported by GDSS and unfortunately the design of the previous study fails to do this.

In the next section, we introduce a design to remedy the problem.

III. A Design for Supporting Convergent Process

A. *Basic Approach*

We simply designed a joint procedure of two opinions by following two steps: 1) one participant presents a new opinion, 2) the other supports the opinion. Fig 3 is the illustration. At first, each of X1 and X2 has a unique list. Next, X1 represents a new list that reflects X2’s preference and X2 has decided to support it. Here, support of X1 by X2 means renouncing X2’s original plan and results in invoking a joint opinion.

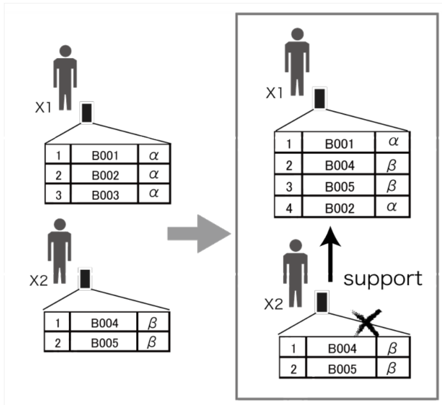

Fig. 3. Process of Jointing Two Opinions

Here, we excluded the synchronization aspect of vote counting; in the new design, each participant can vote for any idea presented in the system at any time, and the vote count remains unchanged after altering the list. For example, in Fig 3, the previous vote count for X1 remains the same after X1 altered their opinion. The previous vote count for X2 will be added to the vote count of X1 after X2 gives support to X1(Votes by the same participant are automatically deducted from the total).

This approach is simple and can avoid the drawbacks of the previous design, although a more detailed design for the vote count framework is needed. The formal description of this new framework is given as follows.

B. *Formalization*

The set of all participants is denoted as P. Some members of P are managers who can start a decision making process. The set of managers is denoted as M $(\subset P)$.

Decision making is designed as a procedure to create a plan to submit to a manager. (Generally in this formalization we use the term ‘plan’ to refer to alternatives or opinions.) A plan is a list of elements of I that is a set of attractive items to receive. We represent that a plan A is a list of items $i_n \in I(n = 1,..., N)$ as following:

$$A = (i_1, i_2, ..., i_N)$$

The order of elements in a list indicates the order of preference.

Any manager $m \in M$ is able to start a decision making process by setting Cm, $Rm \in P$, and $Em \in P$. Cm is a set of conditions for a plan to be selected. Rm is a set of representatives that are participants who can submit alternatives (plans). Em is the set of evaluators that are participants who can evaluate alternatives submitted by representatives. In many cases, each of Rm and Em is the set of $P - \{m\}$.

<Plan Submission by a Representative>

Each representative can submit or alter their plan at anytime. We represent that A is the plan of version i presented by representative $r \in Rm$ as the following:

$$A = submit(r, i).$$

Simple $submit(r)$ means a plan of the newest version submitted by r. $State(r)$ refers to an attribute that reflects the state of a representative. The range of function $State$ is the set $\{Null, Independent, Supportive\}$. $Null$ is the state of a representative that has not submitted a plan yet. It turns to $Independent$ after submitting a plan. Again, it turns to $Supportive$ if the representative gives support to one of the other representatives.

<Evaluation by Evaluators>

We denote evaluation of plan A by $e \in Em$ as $eval(e, A)$. The range of function $eval$ is {0, 1}. 0 refers to a low evaluation and 1 refers to a high evaluation. The default value is 0.

$V(r)$ refers to the set of all evaluators who support representative r at the moment. That is,

$$V(r) = \{e \in Em \mid eval(e, submit(r)) = 1\}$$

Each evaluator can alter their evaluation at anytime.

<Organization of Representatives and Vote Accumulation>

A representative $r1 \in Rm$ can *support* another representative $r2 \in Rm$ if both of $State(r1)$ and $State(r2)$ are $Independent$ at the moment. A supportive representative can cancel their support for another representative at anytime. In the case of cancellation, the state of the representative returns to $Independent$ from $Supportive$. The set of all representatives who support r is referred to as $S(r)$. $S(r)$ doesn’t include r. The supporting relationship among representatives constructs tree structures.

To count the total number of supporters who are in the subtree where r is the root node, we define the set $TV(r)$ and the function $Score(r)$ as follows:

$$TV(r) = \begin{cases} V(r) \cup (\bigcup_{s \in S(r)} TV(s)) ... (S(r) \neq \phi) \\ V(r) ... (S(r) = \phi) \end{cases}$$

$$Score(r) = | TV(r) |$$

<Decision>

At the conclusion of the discussion process the plan with the maximum number of $Score(r)$ is selected as the final output of the decision process.

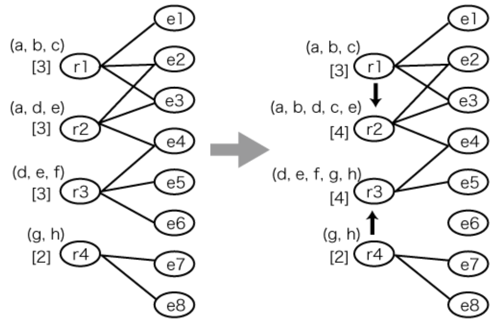

Fig. 4. Convergent Process among Representatives (1)

Fig. 4 is an illustration of a convergent process in the system. Here, $rn(n = 1,...,4)$ and $en(n = 1,...,8)$ refer to the representatives and the evaluators respectively. A list near to a representative is the current plan of the representative. Each line between a representative and an evaluator shows the evaluator’s vote for the representative and a number near to a representative is the vote count. In the left part of the figure, r1 has a plan of (a, b, c) and is supported by three evaluators of e1, e2, and e3. The right part of the figure shows the subsequent scene. Here, r2 and r3 altered their plans to gain the support of r1 and r4 respectively. r1 and r4 gave their support to r2 and r3 respectively, and at the same time, e6 who previously voted for r3 canceled their vote. This shift left both r2 and r3 with four votes each. Note that any overlapping vote count is automatically removed.

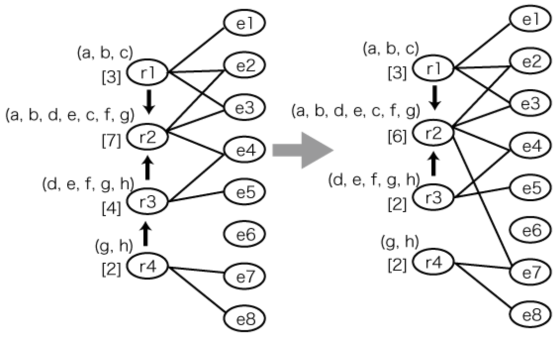

Fig. 5. Convergent Process among Representatives (2)

Fig5 is an illustration of the subsequent scenario. In the left

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part of the diagram, r2 altered their plan again to successfully gain support from r3. On the right part, as a reflection of the change to r3's attitude, r4 canceled their vote for r3. At the same time, however, e7 who is now divided from the tree structure of supporting r2 has expressed their support of r2 directly. At this moment, r2 has the maximum vote count of six and if the time has run out, the plan of r2 is selected as the final output.

Here, as in the illustration, convergence is designed to be enhanced by the motives of representatives who wish to have their plans accepted.

The remaining problem to be addressed is implementation of the design and its evaluation.

IV. Implementation and Evaluation

A. Infrastructure for Group Communication

First, we developed a social networking website as an infrastructure for group communication using one of the leading social networking platforms in Japan, OpenPNE. In our design of the SNS, users are expected to register with a real name, that is, the SNS provides users with a space to communicate using their real names. It is a system for daily communication that precedes decision making. As in other conventional SNSs users can add friends, send messages, and update their personal profiles.

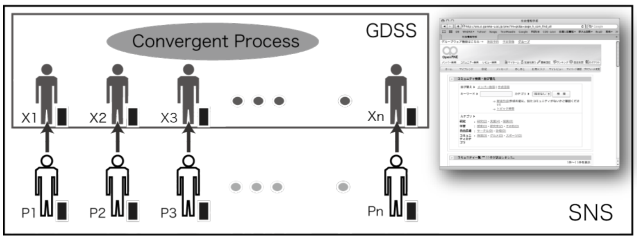

Fig. 6. GDSS and a Communication Infrastructure

Fig. 6 illustrates the relationship between our GDSS and the SNS. Each user with a membership of the SNS is able to access the GDSS and can act as a representative and an evaluator. In GDSS, a user is able to communicate with others using a handlename. The anonymity of each user is absolutely guaranteed and even a database manager can't easily identify an anonymous user in the GDSS.

B. System Framework

Fig. 7 shows an interface of the GDSS we developed. The table of four rows in the upper part of the figure is the area for buttons to operate the system. Users use buttons in the upper three rows to input book data that they already possess, and get new book information from the system in preparation to join the decision making process. This preparation part is based on the design presented by [5]. It involves an internal collaborative filtering system. Using archived data in the Internet, we implemented a prototype system which includes data from 5,089 volunteer users and 335,132 documents that belong to the users (the data helps to make the calculation of the recommendation list more reliable).

The bottom row is the interface of the target GDSS. Button A is for making a plan, B for discussion among representatives, and C for evaluation by evaluators.

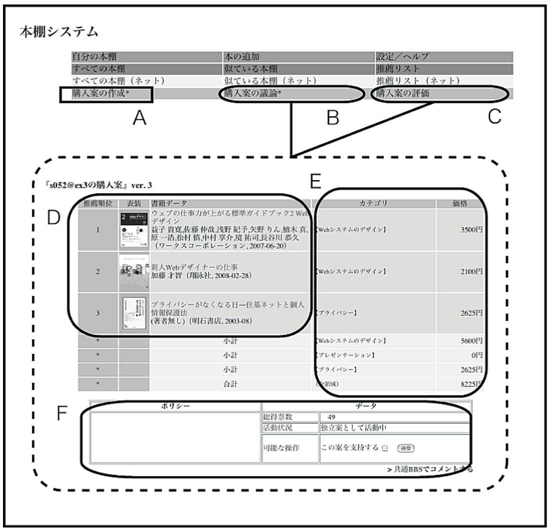

Fig. 7. An Interface for Decision Making

The data within the dotted line in the lower part of Fig. 7 is information that is to be shown in the page of B and C. Although for simplicity only information for one plan presented by a representative is shown here, the real page includes information for all the plans of every representative. Part D describes basic book data in preferential ranking order. E shows additional book data regarding the conditions of decision making (Cm). F is a table that shows votes for the plan, policy description by the representative who submitted the plan and a link to a BBS where users can write comments anonymously.

We opened the system on December 4th in 2008. The system registered 580 students as potential users e.g. students with the right to access the system. All students belonged to one of the national universities in Japan. 341 students (58.8%) actually accessed the system and 248 (42.8%) inputted their data.

C. An Experiment and the Evaluation

We conducted an experiment for document selection as described in the section II. As for category conditions, we stipulated selected books should belong to one of three categories: Web System Design, Presentation, and Privacy. The total cost of the books should be around 20,000 Japanese yen. Nine anonymous users (1.6%) acted as representatives. As a result, using the inclusion rate as the scale of correlation between the different plans, we observed a convergence effect among multiple plans. Even though the remaining 239 users chose to act simply as evaluators and did not submit their own plans, we were able to observe a good convergence effect here, too. But, as described in the following, convergence observed among representatives is more important.

Fig. 8 is the illustration of the process. Each small circle refers to a plan. Each letter in a circle refers to a representative who submitted the plan, and the following number refers to the version of the plan. For example, the circle titled 'B2' refers to the second plan submitted by B. The 'Step' number indicates the position in the process and

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increases each time one of the representatives newly submits or alters a plan. It took 29 days from Step 1 (the step that the first representative submitted their first plan) to the final Step 24. The experiment was concluded on the 33rd day due to time limitations.

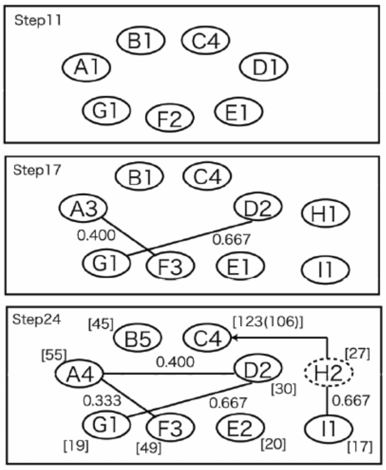

Fig. 8. Convergent Process in the Experiment

As shown in the upper part of Fig. 8, seven plans of A1, B1, C4, D1, E1, F2, and G1 are observed at Step 11. Each of the plans consists of one to four book titles. At this point the plans have no relationship with each other.

At Step 17 all of the nine plans have been submitted. At this point the newly submitted H and I did not share a book with any of the other lists. However, we observed a correlation score of 0.400 between A and F, and 0.667 between D and G. It is evident that some relationships are emerging among the plans; Step 17 has a more convergent structure than Step 11.

Step 24 is the final step observed in the experiment. Here, representative A has a new relationship with D (correlation score is 0.400), although amendments to the plan weakened the relationship with F (0.333). There also emerged a new relationship between H and I (0.667). Each number in the [] notation indicates the vote count at this final stage. H with 27 votes supports C that has already obtained 106 votes. This support by H gives 17 votes to C and the C vote increases to 123. (10 of the 27 evaluators who voted for H are already among the 106 evaluators who voted for C. The overlapping vote count is automatically removed.) As the result of the decision process, C's plan with a total vote of 123 was selected as the final plan to be sent to a manager.

Although at first no common item was found among the nine plans, as shown in the above process, we observed a convergence effect in the consequent decision making process where many of the plans were frequently altered to attract other representatives. Now, the explanation of the experiment is completed.

V. Concluding Remarks

This paper presented a new design for a Web-based GDSS that supports anonymous communication for the convergent process. We implemented a prototype system and evaluated it with a decision making experiment of document selection.

Recent study related to maintaining well-ordered discussion as in this study includes [1], [2] and [7] that visualize discussion structures for the purpose of supporting participants or facilitators. It is characteristic of this study to focus not on the discussion structure itself but on the system design in which the movement towards convergence is enhanced by the motives of representatives who wish to have their plans accepted.

In terms of self-management by the group, this study is also related to [8] that proposed a framework in which a possibly illegal document in a communication system is concealed. However, our framework of self-management by the group deals with the plans by noting evaluation scores instead of documents written in a natural language.

Although this paper focused on a specific example scenario of book recommendation, the design can also be applied to various other fields that need convergent discussion among many anonymous users. To check its effectiveness level in other fields, a prototype system with a more detailed design needs to be developed and experiments undertaken. These are tasks for the next stage of our studies.

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