DISCUSSION VISUALIZATION ON A BULLETIN BOARD SYSTEM

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ABSTRACT

It is important for a collaborative community to decide its next action. The leader of a collaborative community must choose an action that increases rewards and reduces risks. When a leader cannot make this decision, action will be determined through community member discussion. However, this decision cannot be made in blind discussions, so systematic discussion is necessary to choose effective action in a limited time. In this paper, we propose a bulletin board system framework in which effective discussion is established through visualized discussion logs.

Keywords: Bulletin board system, Information visualization, Discussion support, Comment criteria, Discussion divergence, Discussion convergence

1 INTRODUCTION

It is important for a collaborative community to decide its next action. The leader of a collaborative community must choose an action that increases rewards and reduces risks. When a leader cannot make this decision, action will be determined through community member discussion. However, this decision cannot be made in blind discussions, so systematic discussion is necessary to choose effective action in a limited time. In addition, the repetition of divergence and convergence in the discussion according to members' common knowledge and background will lead to an effective conclusion.

We propose a bulletin board system (BBS) framework that supports discussion divergence and convergence for deciding a series of actions to be undertaken. This BBS framework provides an environment in which the remote community members can participate in systematic discussions. In this framework, as the scenario must be stream-like, a sub-story model that supposes consecutive appearances of the same words is incorporated.

Rather than interpreting previous discussions, this study aims to smoothly control current and necessary discussions. That is, the system grasps each state of the discussion, indicates the type of opinion, and supplies environments for constructive discussions.

The background for this paper is described in section 2, and a BBS framework is proposed in section 3. Evaluation criteria for each comment in BBS are determined in section 4. Experimental results are shown in section 5, and section 7 concludes this paper.

2 BACKGROUND

Many related works have analyzed the co-occurrence of words in individual user comments (Ohsawa, Soma, Matsuo, Matsumura, & Usui, 2002) or visualized the structure of mutual citations (Matsumura, Ohsawa, & Ishizuka, 2002). In this study, although co-occurrence is also incorporated, we suggest a system to measure discussion streams that expands from two to three or more comments in which consecutive words appear.

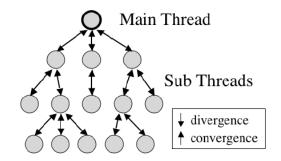


Figure 1. Divergence and convergence of threads in BBS

Since there is a lexical chain (Morris & Hirst, 1991) in natural language processing, this system is regarded as the application of a lexical chain without a thesaurus. A topic extraction method (Hearst, 1994) extracts relationships in a story with a Text-Tiling method. However, such a system cannot be applied to bulletin board systems that contain various comments by multiple members. In this study, the framework assumes multiple sub-topics, loosely related in comment streams.

To measure the relationship between segments in a document, a Vector Space Model (Salton, Wong, & Yang, 1975) is generally used, where the angle between two vectors is the relationship. However, this is insufficient for estimating a document stream because the angle is defined in only two segments. In addition, although there is a sentence ordering system for summarization (Lapata, 2003), our study examines continual document streams.

Matsumura et al. (2002) analyze the discussion structure for finding and comprehending topics. In this study, topics are given, and BBS supplies suggestions to control discussion progress.

3 THE SUPPORT BULLETIN BOARD SYSTEM

In this section, we describe a BBS system framework that supports discussion control by the sub-story model described in the previous section. According to these preliminary experiments results, similar linguistic expressions are used continuously, and most words in a document tend to appear in a short range of segments independent of part of speech. In other words, the words appeared in consecutive segments as often possible.

Nouns and verbs in particular are likely to appear continuously because they are used as subject and predicate in each sentence. On the contrary, other repetitions of parts of speech may be caused unconsciously because of writing habits.

In this study, we apply this concept by regarding a thread in a BBS as a document and a segment as a comment written by a community member. The system supplies implications of each comment's status by regarding the consecutive appearing words as the appearance of the document stream.

The person who controls the discussion is not a system but a leader and a member of the community. The system clarifies the placement of each comment in the flow of the topical discussion, implies byways or unrelated comments, and urges comments to include necessary elements. Terms and environments for the BBS framework are defined as follows:

- BBS: a discussion environment for community members using the Internet; a set of threads.

- Thread: a blackboard system in which members can discuss the topic by writing comments; a set of comments.

- Comment: a member's written opinion.

Discussion streams

The discussion procedure for problem solving from topic suggestion to a conclusion containing a solution is as follows:

Discussion Process

- 1. Create a thread of the main/sub-topic.
- 2. Discuss differing opinions and ideas in the divergence phase.
- If a sub-topic is suggested, a) For the sub-topic, follow procedures 1 to 5.
 - b) Embed its conclusion.
- 3. Change from divergence phase to convergence phase.
- 4. Discuss bringing together the collected opinions in the convergence phase.
- 5. Create conclusions for the main/sub-topic.

This procedure is similar to the relationship among the main function and the sub-functions in computer programming, as shown in Figure 1. The tree structure expresses problem occurrence and divisions. A large problem is divided into small problems recursively to solve more concrete problems and to accumulate the solutions.

In the rest of this section, the procedure of this process is described.

Creation of a thread A community leader establishes a main topic and creates a new thread for discussion. A community member creates a new thread by creating a sub-topic in the divergence phase. The following are the types of threads:

- Main: thread about main topic created by the leader of a community.
- Sub: thread about a sub-topic created by a member of the community.
- Byway: thread about a secondary additional topic that does not affect the solution of the main topic.

By creating a thread for each divided distinct topic, members can concentrate on discussing one topic, and the system can grasp states of the thread.

Divergence Phase Discussion is divided into two phases: divergence and convergence. In the divergence phase, members hold discussions to collect opinions. The rate of divergence is simply measured by new words. However, if the topic spreads blindly, discussion will not converge. Therefore, the system supports discussion control in the range of the topic and supports the various opinions of members.

Creation of a sub-thread In the divergence phase, if it is clear that conditions for solving the topic of the current thread exist, and if the members acknowledge that they are valid, a new sub-thread is created by the member who set those conditions.

Transitions from Divergence to Convergence Phase After most opinions have been added to the thread, the discussion phase switches from divergence to convergence.

That is, if there is a discussion that exceeds the threshold, calculated by the number of relational keywords of the topic, the number of sub-threads, and the discussion time from when the thread was created, a transition is suggested to the member who created the thread. If the member agrees, the transition will be executed.

Convergence Phase In the convergence phase, a new discussion is not needed, but discussion continues to converge opinions and already obtained conclusions. Therefore, the rate of new words is minimized by the suggestions of the system. In addition, to converge the sub-thread conclusions, new comments using multiple

topics of sub-threads are recommended; sub-topics supplied by order of occurrence and comments, including adjacent topics, are recommended.

Create topic conclusions When the comments, including the oldest subtopic, and all topics have appeared, the system urges the member who created the thread to create conclusions. After conclusions are declared, the thread is closed.

Conditions to Comments

Members write their opinions in the threads as comments. However, since it is hard to control discussions written in a free format, conditions are attached to the comments for discussion analysis based on the sub-story model. The system recommends that users write new comments including consecutive words, while the system examines each comment to ensure that it conforms to the topic and the discussion stream. The following conditions are highly recommended for each comment:

- Use the topic word in the thread.
- Use words already used in the same thread.
- Avoid pronouns.
- Use new relational words of the topic in the divergence phase.
- Use multiple words for sub-topics in the convergence phase.

These suggestions help users write comments for systematic discussions, such as retention of logical relationships, divergence, and convergence. To write a comment under these conditions, concrete numerical criteria and comments evaluation criteria are calculated and displayed.

4 COMMENT EVALUATION CRITERIA

In this section, eight comment evaluation criteria for discussion control are described. Six criteria are word evaluations used in each comment, and the other two are status evaluations in discussion streams. The criteria are as follows:

- 1. Topic: relevance to the topic
- 2. Flow: continuity related to the topic
- 3. New: new tips related to the topic
- 4. Inc: incorporation to the topic
- 5. Byway: continuity unrelated to the topic
- 6. Flood: new tips unrelated to the topic

Criteria from 1 to 6, which are calculated by evaluating words in each comment, involve relationships with the topic words. Finally, criteria for divergence and convergence are prepared from a combination of these six criteria.

- 7. Div: divergence for discussion
- 8. Conv: convergence for discussion

In the rest of this section, these criteria are defined precisely, and "words" mean nouns extracted from each comment. In the future, "words" can be replaced by a set of parts of speech or real words depending on BBS type or language.

Distance between words

A criterion is defined as the word distance denoting the relevance between two words. A corpus is not available

because words relationships are dependent on the topic and its contexts.

First, the distance value in comment C between words w_i and w_j is calculated by Eq. (1):

$$distance(w_i, w_j, C) = |ia(w_i, C) - ia(w_j, C)|,$$
(1)

where ia(W,C) is a function that gives the number of words between the top of comment C to the first appearance of word W. This distance assumes that a word should be defined at its first appearance as an opinion of the comment.

By using this distance in a comment, preliminary distance (*pre_dist*) between words W_1 and W_2 for *n*-th comment in a thread is defined as Eq. (2):

$$pre_dist(W_1, W_2, C_n) = \min_{\substack{i=1\cdots n}} \{ distance(W_1, W_2, C_i) \}.$$

$$(2)$$

This preliminary distance assumes that a member writes a comment referring to the former comments and learning relationship among words in the thread.

Word labeling

Each word in each comment is labeled according to its role. The definition of each label is as follows. Figure 2 shows their relationship.

- 1. TOPIC: topic words
- 2. FLOW: previously appearing words related to topic
- 3. NEW: new words related to topic
- 4. INC: words incorporated from unrelated into related ones
- 5. BYWAY: previously appearing words unrelated to topic
- 6. FLOOD: new words unrelated to topic

Relevance threshold *dmax* is defined as 10, which is the maximum distance from one of the topic words. Word *W* is related to the topic if and only if the distance between *W* and one of the topic words is smaller than *dmax*. This threshold is defined by preliminary experimental results where a meaningful sentence includes at least seven words (Sunayama, Iyama, & Yachida, 2006). A related word should be included in three sentences: a sentence containing a topic word, the former, and the latter for the relationship. Therefore, 20 words are relational except a topic word, and the threshold distance is reduced by half.

New words will be labeled either NEW or FLOOD based on their distance from a topic word. Previously appearing words, based on the transition in Figure 2, are labeled FLOW if they were initially labeled NEW. If a word was initially labeled FLOOD, that word is labeled BYWAY if its distance from a topic word is no less than *dmax*; otherwise it is labeled INC. A word is labeled unrelated to the topic as long as it appears far from topic words.

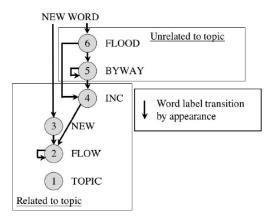


Figure 2. Word's labels and its transitions

Criteria for topic relevance

Topic relevance of k-th comment C_k in the thread is given by Eq. (3) as the sum of the minimum distance to each topic word and its normalization, where *n* is the number of topic words and *dmax* is the distance threshold defined in 4.2:

$$topic(C_k) = 1 - \frac{1}{n \times d \max} \sum_{i=1}^n d_i.$$
(3)

In addition, the minimum distance value from i-th topic word in k-th comment C_k is defined as Eq. (4):

$$d_{i} = \min\left\{ d \max, \min_{j} \left\{ pre_dist(T_{i}, c_{j}, C_{k-1}) \right\} \right\}.$$
(4)

That is, for each word $\{c_j\}$ in comment C_k , d_i is set to the minimum preliminary distance from each topic word $\{t_i\}$ in topic word set T until (k-1)-th comment. If d_i exceeds dmax, d_i is set to dmax.

As a result, topic relevance is one if a comment is the most related to the topic and is zero if a comment is the least related. This criterion evaluates the relevance to all topic words of the thread because all comments should be written along the established topic of a thread.

Even if a comment does not include any topic words, topic related words such as those labeled FLOW are counted as being on topic. Because of this calculation of secondary topic relationships, a comment need not always include topic words.

Criteria for each word

Topic continuity, topic novelty, topical incorporation, unrelated continuity, and unrelated novelty of k-th comment C_k in the thread are given by Eq. (5) - Eq. (9) respectively, where *number*(*C*, *LABEL*) denotes the number of words labeled *LABEL* in a comment *C*.

$$flow(C_k) = number(C_k, FLOW).$$
(5)

$$new(C_k) = number(C_k, NEW).$$
(6)

$$inc(C_k) = number(C_k, INC).$$
⁽⁷⁾

$$byway(C_k) = number(C_k, BYWAY).$$

$$flood(C_k) = number(C_k, FLOOD).$$
(8)
(9)

Topic continuity *flow* evaluates the contribution to creating a discussion stream by using words related to the topic of a thread. If a comment is written by many topical words used in former comments, *flow* becomes large.

Topic novelty *new* evaluates the contribution to the provision of new tips related to the topic of a thread. If a comment includes new ideas or information related to the topic, *new* becomes large.

Topical incorporation *inc* evaluates the contribution to the incorporation of unrelated words used in the former comments. If a comment connects unrelated former comments with the topic, *inc* becomes large.

Unrelated continuity *byway* evaluates the disturbance to the discussion by the continuous use of unrelated words used in the former comments. If a comment succeeds unrelated former comments without connecting to the topic, *byway* becomes large.

Unrelated novelty *flood* evaluates the disturbance to the discussion by providing new tips unrelated to the topic of a thread. If a comment includes new ideas or information that does not seem to be related to the topic, *flood* becomes large.

Criteria for discussion

Discussion divergence of k-th comment C_k in the thread is given by Eq. (10) as the rate of new words above word variety, where variety is the kind of word in comment C_k :

$$div(C_k) = topic(C_k) \times \frac{new(C_k)}{variety(C_k)}.$$
(10)

This criterion is used for progress and promotion of discussion divergence related to the topic of a thread. If a comment includes new ideas or information and is definitely related to the topic, *div* becomes large. For discussion divergence, new related tips are the most desirable.

Discussion convergence of k-th comment C_k in the thread is given by Eq. (11) as the divergence criterion, the rate of FLOW, INC, FLOOD, and BYWAY words above the number of words in the comment C_k as *Allnum*(C_k).

$$conv(C_k) = topic(C_k) \times \left\{ 1 - \left| div(C_k) - (1-t) \right| - \left| \frac{flow(C_k) + inc(C_k)}{Allnum(C_k)} - t \right| - \frac{flood(C_k) + byway(C_k)}{Allnum(C_k)} \right\}.$$
(11)

That is, discussion convergence consists of t % of FLOW+INC and (1 - t) % of divergence except FLOOD and BYWAY because convergent comments should have well-defined words from the former discussion as well as new convergent knowledge. Currently, the rate of t is set to 0.85 by the experimental results in section 5. If convergence becomes negative, it is set to zero.

This criterion is used for the progress and promotion of discussion convergence related to the topic of a thread. If a comment includes new words representing the whole discussion in the thread, *conv* becomes large.

Significance of comment criteria

By displaying these described comment criteria, a community leader can eliminate unnecessary comments and encourage members to write more adequate comments. Such comment criteria are not visible in an ordinary BBS.

Members writing comments labeled BYWAY or FLOOD will be made aware that they are straying from the topic and will be able to change their contributions to the discussion, so they are relevant to the topic at hand.

In addition, all members can grasp how smoothly a discussion is evolving as each comment position is revealed. Therefore, members can have a wide vision of the discussion status, such as its stream and progress.

5 EXPERIMENTS ON DISCUSSION DIVERGENCE AND CONVERGENCE

We did some experiments on the comment evaluation criteria for discussion divergence and convergence as described in the last section. The texts for these experiments were the 100 papers from the eighteenth annual conference of the Japanese Society of Artificial Intelligence. Each paper consists of four pages with about six segments. The papers were in Japanese, and nouns were extracted in advance by a Japanese morpheme analysis system (Asahara & Matsumoto, 2000).

Beginning sections of a paper tend to have a large divergence value, and end sections tend to have a large convergence value. The following text files were prepared for comparison:

- TEXT-O: original papers

– TEXT-B: papers that exchanged the first and second sections

- TEXT-C: papers that exchanged the last and the next to last section.

Table 1 shows the averaged divergence value and the averaged rates of the largest values in each paper for the first and the second segments. In TEXT-O, the rate of the first segment was 79%, which is larger than the second by 65%, though the values were almost the same in TEXT-B. Therefore, the divergence criteria captured the fact that the segment "Introduction" was divergent in relation to the topic of each original paper.

Table 1. Averaged divergence values and rates having best value in each paper for first and second segments

| text | Avg div-segment1 (best) | Avg div-segment2 (best) | Difference | |
|--------|-------------------------|-------------------------|------------|------------|
| TEXT-O | 0.67 (79%) | 0.37 (14%) | | 0.30 (65%) |
| TEXT-B | 0.49 (48%) | 0.48 (41%) | | 0.01 (7%) |

Table 2 shows the averaged convergence values and the averaged rates of the largest values in each paper for the last (L1) and the next to last (L2) segments. In TEXT-O, the rate of the last segment was 74%, which is larger than the next to last by 62%, and the next to last was the most in TEXT-C. Therefore, the convergence criteria captured the fact that the segment "Conclusions" was the most convergent in relation to the topic of each original paper.

Table 2. Averaged convergence values and rates having best value in each paper

| text | Avg conv-L1 (best) | Avg conv-L2 (best) | Difference | |
|--------|--------------------|--------------------|------------|------------|
| TEXT-O | 0.53 (74%) | 0.32 (12%) | (|).21 (62%) |
| TEXT-C | 0.36 (30%) | 0.43 (53%) | -0 | .07 (-23%) |

Finally, Figure 3 shows the relationship between *t*-parameter and convergence in TEXT-O. Convergence should become large in the last segment but small in the next to last. Therefore, the *t*-parameter was set to 0.85

for the difference to become large. As a result, a paper consists of 85% previously appearing words and 15% new words in the concluding summary and future directions sections.

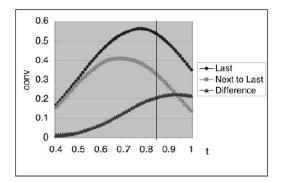


Figure 3. Relationship between t-parameter and convergence in TEXT-O

6 VISUALIZATION FOR EFFECTIVE DISCUSSION

In discussion logs, each word is colored according to its label as in Table 3. That is, users can see the color of discussion logs and ascertain the state of discussion. If logs are filled with brown, black, and blue, such discussion is highly concentrated but the conclusion may be normal. If logs are filled with red and purple, such discussion is fragmentary, and the contents are not integrated. One of the ideal patterns of discussion is:

All colors appear and are in balanced proportion in the logs.

Table 3. Label colors and discussion interpretation

| Label | color | Interpretation |
|-------|--------|---------------------------------------|
| TOPIC | brown | theme oriented discussion |
| FLOW | black | succeeding discussion or repetition |
| NEW | blue | contributing to discussion divergence |
| INC | green | relationship definition |
| BYWAY | purple | barrier to discussion |
| FLOOD | red | possible discussion divergence |

Besides the brown, black, and blue words, red words may lead to a new direction in the discussion. Some discussion is needed about the red word in order to decide whether to incorporate them or not. This consideration will be appear as purple words, and incorporated red words become green.

Other information retrievals are also included in this visualization framework. The discussion logs are narrowed down by users ID numbers, specific keywords, or specific colors:

- If comments related to the specific keywords, such as topic words or incorporated words, are visualized, members can interpret the discussion for the keywords and see their history.

- If comments are narrowed down by specific colors, members can read only effective or non-effective comments.

- The logs of a member, whose comments include many red and purple words, may be eliminated. On the other hand, the comments that include green incorporated words can be selected by seeking a member who makes the connection between the theme (brown words) and undefined topics (red or purple words).

In addition to the above visualization frameworks, a thread is divided into topical terms. The total number of each label in a thread is counted, and this counted label-balance must vary at the terminal points. Therefore, the system detects such varying points and visualizes the thread structure.

7 CONCLUSION

In this paper, a bulletin board system framework for discussion visualization using a sub-story model is proposed. To control the discussion stream of divergence and convergence, consecutive word appearance in a document stream model is applied. Criteria for divergence and convergence are evaluated by research papers as imitative discussion.

In future works, a concrete system will be constructed and discussion support realized and evaluated. Visualization methods will be enhanced as a network displaying discussion divergence, convergence, users' roles, and their relationships. A scenario for the desirable future will not be created without cooperation among all members and their consciousness.

8 **REFERENCES**

Morris, J. & Hirst, G. (1991) Lexical Cohesion Computed by Thesaural Relations as an Indicator of the Structure of Text. *Computational Linguistics* 17(1), pp. 21 - 48.

Salton, G., Wong, A. & Yang, C. S. (1975) A Vector Space Model for Automatic Indexing. *Communication of the ACM* 18(11), pp. 613 – 620.

Sunayama, W., Iyama, A. & Yachida, M. (2006) HTML Text Segmentation for Web Page Summarization by Using a Key Sentences Extraction Method. *Systems and Computers in Japan*, John Wiley & Sons, Inc., 2006.

Ohsawa, Y., Soma, H., Matsuo, Y., Matsumura, N., & Usui, M. (2002) Featuring Web Communities based on Word Co-occurrence Structure of Communications. *Proc. of 11th International World Wide Web Conference*, Honolulu, Hawaii, USA.

Matsumura, N., Ohsawa, Y., & Ishizuka, M. (2002) Influence Diffusion Model in Text-based Communication. *Proc. of 11th International World Wide Web Conference,* Honolulu, Hawaii, USA.

Hearst, M. A. (1994) Multi-paragraph segmentation of expository text. *Proc. of the 32nd conference on Association for Computational Linguistics*, pp.9 – 16.

Lapata, M. (2003) Probabilistic Text Structuring: Experiments with Sentence Ordering. *Proc. of the 41st Meeting of the Association of Computational Linguistics*, pp.545 – 552.

Asahara, M., Matsumoto, Y. (2000) Extended Models and Tools for Highperformance Part-of-Speech Tagger. *Proc. of the 18th International Conference on Computational Linguistics*, 1, pp.21 – 27.