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Method for Evaluating Participants' Roles in Online Text Discussion Using Network Analysis

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Abstract: We propose a method for evaluating participants' roles in online text discussion using network analysis of chat log data. In our method, we use log data to construct a statement network indicating the relativity of the statements. We evaluate the participants' role by calculating four types of point centralities. Experiments have been conducted to evaluate our method. The results from our method closely correspond to participants' peer assessment data. This indicates that the proposed method is effective.

Keywords: CSCL, Discussion support, Role analysis, Network analysis, Morphological analysis

Introduction

Research into computer-supported collaborative learning (CSCL) is an active research field in educational technology. In collaborative learning, learners try to solve problems and acquire other learners' knowledge through discussion with other learners in a group [1]. Our aim is to support learners in improving their discussion abilities as a part of CSCL. However, before thinking about methods of support, we must first evaluate participants' roles in the discussion. One method of evaluation is the use of peer assessment of the other participants' roles, but this is difficult for learners to do in every discussion. We therefore propose a method of evaluating participants' roles using chat log data to achieve our aim. The number of statements which identifies the most loquacious speaker, however, can not evaluate participants' roles. Therefore, we propose a method that uses log data to analyze discussions. Erlin et al. introduced researches about content analysis and network analysis, and argued that the integration of content analysis and network analysis provides a scientific and systemic way to analyze the quality of asynchronous discussion forum [2]. Network analysis is used in the study of the structure and behavior of social networks [3]. Network analysis can be applied to analyze the process of decision-making in group discussion or the human relationship in online discussion [4][5].

This paper proposes a method of network analysis that uses chat log data to evaluate participants' roles in online text discussion. We construct a statement network, in which the node is a statement and the link is the relativity of statements, and detect central statements by calculating point centralities. We evaluate participants' roles by focusing on the speaker of the central statements. In the experiments, participants hold Japanese discussion and English discussion through online chat and assess the other participants' behaviors in the discussions. We compare the results from our method with those from peer assessment data to evaluate the validity of the method. We also compare the discussions in Japanese and English to evaluate changes in participants' roles by language skill.

1. Method for Evaluating Participants' Roles in a Discussion

We assume that the discussion is online text discussion in CSCL. Statements are extracted along with input time and input person from the chat log data.

We indicate the overview of our method. Network analysis is a method for determining the relationship structure of components in various objects [6]. Collaborative learning is carried out through human relationships. Network analysis is useful in the analysis of discussion in the context of collaborative learning. We construct a network model using the log data to apply network analysis to discussion analysis (Figure 1).The influence or characteristics of statements are important in analyzing the participants' roles. We assume that similarity of words in the statements and the statement order is important to assess the influence and character of statements. Therefore we take statements' similarity and order as the relativity of the statements. Our proposed method consists of three steps: for the first step, we set statements as nodes and the relativity of statements as links to form a network. Second, we extract central nodes in the network by calculating point centralities to find central statements. Third, we evaluate the participants' roles by focusing on the speakers with the statement influence and character. Next we show the details of each step.

For the first step, we construct the network model. After pre-processing of text (e.g., spelling correction), each statement is broken down into morphemes, and whole terms (noun and adjective) are extracted in order to create a statement network. We choose the statement vector in which elements are calculated by the frequency of terms. Vector elements are weighted by tf-idf weighting to take into account the frequency of occurrence of each term. The weight of the term t in the statement s is determined by equation (1).

$$\mathrm{tfidf}(t,s)=\mathrm{tf}(t,s)\times\left(1+\log_e\frac{N}{\mathrm{df}(t)}\right), \quad (1)$$

where tf(t,s) is the frequency of occurrence of term t in statement s, and df(t) is the number of statements that contain term t, and N is the total number of statements. The distance of the link between the statement i and the statement j, l_{ij}, is determined by the similarity of these statements and the statement order (equation (2)). We adopt as a link when l_{ij} is bigger than 0. A shorter link distances indicates that the relativity of statements is strong, as when the statement j is similar to the statement i or when the statement j is spoken soon after the statement i. We take the cosine similarity as the similarity of these statements (equation (3)).

$$l_{ij}=\frac{\log_2(1+(j-i))}{\cos(S_i\cdot S_j)}. \quad (2)$$

$$\cos(S_i,S_j)=\frac{(S_i\cdot S_j)}{|S_i||S_j|}. \quad (3)$$

For the second step, we calculate four types of point centralities to locate central statements in the formulated statement network (Table 1). Point centrality measures the relative importance of a node within the network [6]. Firstly, degree centrality indicates the influence of a statement since it is determined from the number of links. Indegree centrality is defined as the number of links directed to the node, and outdegree centrality is defined as the number of links that the node directs to others [6]. Therefore, we adopt outdegree centrality as the index of influence to other statements and indegree centrality as the index

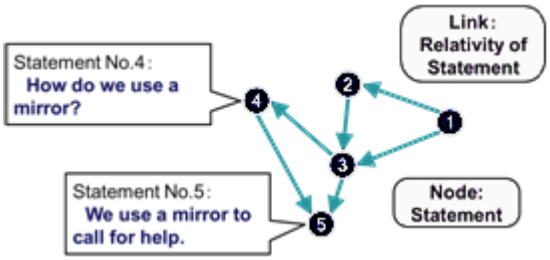

Figure 1 Statement Network Model

Table 1 Type of Centrality

Indication	Point centrality
Influence from other statements	Indegree centrality
Influence to other statements	Outdegree centrality
Change of topic	Betweenness centrality
Central statement in the topic	Closeness centrality

of influence from other statements. In the proposed method, we set a trimmed mean of outdegree centrality and indegree centrality of whole nodes as a threshold, and defined the nodes exceeding the thresholds as influential statements and affected statements.
Secondly, betweenness centrality indicates a statement that changes the topic since it is defined as a cut-point. The cut-point is the node that maintains the connectivity of a network [6]. Nodes that are on many shortest paths between any two nodes have higher betweenness centrality than those that are not [6]. In the network in Figure 1, for example, Node 3 has the highest betweenness centrality. Therefore the node with higher betweenness denotes the statement which changes the topic in a statement network. In the proposed method, we calculate betweenness centrality on a maximal connected component in the whole network since this centrality cannot be calculated on an unconnected graph. We set a trimmed mean of betweenness centrality of whole nodes as a threshold, and defined the nodes exceeding thresholds as the statements that change the topic.
Thirdly, closeness centrality indicates central statements in the topic since it is defined as the sum of shortest paths to the other node [6]. In our method, we calculate closeness centrality on a maximal connected component in the whole network since this centrality cannot be calculated on an unconnected graph. We set a trimmed mean of closeness centrality of whole nodes as a threshold, and defined the nodes exceeding thresholds as the central statements in the topic.
For the final step, we count the number of central statements in every centrality with each participant individually. The roles of each participant are evaluated using the number of central statements, for example, when a participant has many central statements in the betweenness centrality, the participant plays the role of changing the topic in the discussion.

2. Experiment

2.1 Outline of Experiment

We conducted experiments to evaluate our method. Five Japanese students discussed through online text chat. The theme of the discussion was the consensus game, the purpose of which is obtaining consensus among the group members through a discussion [7]. Group members performed an exercise in which they ranked eight items in descending order of importance for survival in a difficult situation [7]. They discussed in Japanese for 50 minutes. After a 30 minute break, they discussed in English for 50 minutes. Their English levels differed greatly, and thus we labeled participants as A, B, C, D, and E according to their English level based on official English scores, such as TOEFL. (The participant with the highest English skill was labeled A.) They used Google Chat as a group chat program and Google Docs Presentation to share information. They were allowed to use online English–Japanese and Japanese–English dictionaries when the discussion was held in English. After the discussion, participants filled in the peer assessment questionnaire on a two-point scale. Participants responded as to whether the other participants exhibited the behaviors listed in Table 2. We conducted experiments with 4 groups.

Table 2 Questionnaire Items

No.	Name	Question
1	Irrelevant	Did he/she make irrelevant statements?
2	Initiative	Did he/she take initiative in the discussion?
3	Coordinate	Did he/she coordinate the discussion?
4	Paraphrase	Did he/she paraphrase the statements of others?
5	Back-channeling	Did he/she give responses to indicate comprehension?
6	Question	Did he/she ask questions of others?
7	Change	Did he/she change the topic?

2.2 Results

We show the results for a representative group. Table 3 shows the number of nodes exceeding thresholds of centralities by participants. The discussion in Japanese had 171 statements and the discussion in English had 207 statements. In the discussion in Japanese, Participant D had many nodes exceeding thresholds in every type of centrality, especially betweenness centrality. These results mean that Participant D's statements not only influenced other statements but also were influenced by other statements. Participant D also changed the topic, and the discussion centered on Participant D's statements. This indicates that Participant D played the role of the leader who took the initiative in changing the topic. In the English discussion, Participant A had many nodes exceeding the threshold in every type of centrality. The results mean that Participant A's statements not only influenced other statements but also were influenced by other statements. Participant A changed the topic and made statements that were central to the discussion. This indicates that Participant A played the role of the leader. During the English discussion, Participant D had fewer nodes exceeding the threshold of betweenness centrality than in the discussion in Japanese. We suppose that the discussion in English was difficult for Participant D to control because of Participant D's relatively low English skill. Moreover, Participants C and E made fewer central statements when the language changed to English, which indicates that they were less active in discussing the topic in English in comparison with the discussion in Japanese.

Table 3 Results of Analysis

	Number of nodes		Maximal connected component		Indegree centrality		Outdegree centrality		Betweenness centrality		Closeness centrality	
	JP	EN	JP	EN	JP	EN	JP	EN	JP	EN	JP	EN
Threshold					2.3	0.97	2.4	0.96	88	52	0.44	0.35
A	57	72	33	43	10	13	8	12	4	7	12	18
B	17	24	17	15	5	4	4	6	3	0	5	6
C	35	39	31	17	7	3	4	5	3	1	9	3
D	34	39	29	23	14	13	13	13	10	5	17	15
E	28	33	22	19	6	5	7	6	1	3	12	7
Total	171	207	132	117	42	38	36	42	21	16	55	49

JP: Japanese, EN: English

3. Discussion

We next compare the results from our method with the results from peer assessment data based on participants' subjective views to evaluate the validity of our method. Table 4 summarizes the results of the peer assessment questionnaire. The number for each behavior indicates the number of participants who responded that the behavior was true. The results obtained by the proposed method indicate that in the Japanese discussion, Participant D played the role of the leader, while in the English discussion, the leader was Participant A. In contrast, the peer assessment data shows that both Participants A and D were seen to act as leaders in the Japanese discussion while Participant A was perceived as the leader in the English discussion. The results from our method closely correspond to the peer assessment data. The peer assessment data shows that E tended to make irrelevant statements in the English discussion, which agrees with the results from our method. On the other hand, our method indicates that in the English discussion, Participant C tended to make irrelevant statement. However, the peer assessment data shows that Participant C instead paraphrased what someone else had said. In our method, we use the similarity of statements as a network link. Thus, the statement S_i is linked to the statement S_j if both statements have a word in common. Therefore, paraphrased statements would not link to relative statements. In summary, the results of analysis with our method using chat log data closely correspond to peer assessment data, showing that this approach is effective.

Table 4 Results of Peer Assessment

	Irrelevant		Initiative		Coordinate		Paraphrastic		Back-channeling		Question		Change	
	JP	EN	JP	EN	JP	EN	JP	EN	JP	EN	JP	EN	JP	EN
A	0	0	3	4	3	3	1	1	3	4	1	2	3	4
B	0	0	0	1	0	2	0	2	4	4	1	1	0	3
C	0	0	1	0	2	0	0	2	3	4	0	1	1	2
D	0	0	3	0	3	1	2	0	3	4	0	2	3	3
E	0	1	0	1	0	1	1	0	4	4	1	0	0	4
Total	0	1	7	6	8	7	4	5	17	20	3	6	7	16

JP: Japanese, EN: English

We then compare the discussions in Japanese and English. The results show that the role of leader changed from Participant D to A when the language changed from Japanese to English. This indicates that Participant A could give opinions more smoothly because this participant had the highest English skill among the participants. Moreover, participants who did not have high English skill tended to make irrelevant statements or lose the role of leader when the language changed to English. In conclusion, we confirm the utility of our method to find the change of participants' role by language skill.

4. Conclusion

In this paper, we proposed a method that uses network analysis of chat log data in order to evaluate participants' roles in online text discussion. The purpose of this analysis is to support the improvement of discussion in CSCL. We constructed a statement network and detected the central statements by calculating point centralities. We evaluated participants' roles by identifying the speaker of the important statements. We then succeeded in evaluating participants' roles by applying our method to the experimental data. This was not possible when simply counting the number of statements. With this method, various aspects of the discussion can be evaluated, for instance, who was the leader and who made the greatest number of irrelevant statements. These results closely corresponded to the peer assessment data. Therefore, this approach based on network analysis is effective in detecting participants' role in online discussion. We also confirmed the utility of our method in observing the change in participants' roles when comparing a discussion in Japanese and English. In this research, we focused on a statement network and analyzed characteristics of statements by calculating centralities. A future objective is to evaluate other roles which could not evaluate from our method using network analysis. Upon further development, our method is expected to be useful in CSCL by facilitating consideration of the participants' roles.

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