Discussion Support Agent System to Promote Equalization of Speech among Participants

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Abstract: Reducing the imbalance of speech length in discussions is expected to improve decision making and collaborative learning. In this paper, we propose a facilitation system based on the cumulative percentage of utterances in discussions. We surveyed the effectiveness of this system on the collaborative learning from the perspective of standard deviation of utterance length and percentage of utterances throughout discussions. we collected 20-minutes discussion data under the topic "What is a thoughtful consideration?" and "What is happiness?" from seven groups of three participants. Each group had two discussions, one with the system and one without the system. The results revealed that the facilitation system decreased subjective and objective imbalance of speech length. Additionally, turn-taking was active in the group which facilitation by the system was effective.

Keywords: Discussion support agent system, dialog analysis, facilitation, collaborative learning, percentage of utterances

1. Introduction

Recently, small group discussions are used in collaborative learning to avoid social loafing (Latané et al., 1979). Especially, researchers have focused on supporting collaborative learning with technology (DeSanctis & Gallupe, 1987; Alavi, 1994; Jermann tr al., 2001). In collaborative learning, persons are required active participation because persons discuss different ideas and consider these ideas carefully.

However, the imbalance of speech length may occur because of status of the discussion such as the relationship and communication skills of participants. In addition, decision making in discussions are affected by talkativeness (DiMicco et al., 2007). This suggests that the approach to support collaborative learning and increase the productivity of the discussion by equalizing utterance length. Ishikawa et al (2019) shows that participants in discussion can learn co-regulation strategy using agent facilitation based on the percentage of utterances up to 30 seconds before facilitation. On the other hand, this system doesn't have enough effects to equalize the percentage of utterances. If a person speaks much in 30 seconds before the facilitation, that person speak much throughout the discussion.

In this study, we proposed a system for facilitation using the cumulative percentage of utterances in discussions. To consider percentage of utterances throughout discussions, our system can facilitate discussions with less influence from the imbalance of utterances in a short time interval. From the above, we focus on two research questions (RQ):

RQ1: Can the facilitation method using the cumulative percentage of utterances throughout the discussion equalize the percentage of utterances?
RQ2: If the method is effective (or not effective), how the system reduced (or increased) utterance imbalance?

2. Related works

Commonly methods to reduce the number of utterances is that to visualize the imbalance of participation. Bachour et al (2010) proposed the system for avoiding over and underparticipation to indicate how much the individual has spoken. In this study, Matrix of LEDs indicate person's participation levels based on the number of speaks. Similarly, Kim et al (2008) visualized the participation as a figure consisting of a circle representing the imbalance of the utterances and some lines representing the amount of each participant's speech. In addition, Bergsrtom & Karahalios (2007) examined the expression of the Conversation Clock which visualize prosodic features such as a period of silence and volume of speech. There are also ways to express discussion structure using metaphors such as trees and plants (Tausch et al., 2014; Praharaj et al., 2019).

In these methods, all participants can check the discussion status such as the speech imbalance displayed on the table. However, this may be uncomfortable for the reluctant speaker because everyone knows that he or she is not contributing to the discussion. Therefore, we believe that it is suitable to encourage the participation of the speakers by facilitating them while the agents maintain the audio features. One such approach is using robots (Miyake et al., 2012). However, it may be difficult to prepare robots for actual discussions because they are expensive. In anticipation of such application to actual discussions, the facilitation agent system proposed by Ishikawa et al (2019) was used. The facilitation system can be used in a variety of settings as long as there are displays and polarizers to project the agents, microphones, and computers to run the system.

3. A Facilitation system based on the percentage of utterances throughout discussions

3.1 Overview of the facilitation system

Figure 1 shows the system configuration. Our system consists of two parts: discussion analysis part and agent control part. The discussion analysis part calculates the speech imbalance based on the speech collected by the wearable speech collection device and sends a request to the agent control part according to the degree of the imbalance. The agent control part operates the holographic agent using request sent by the discussion analysis part.

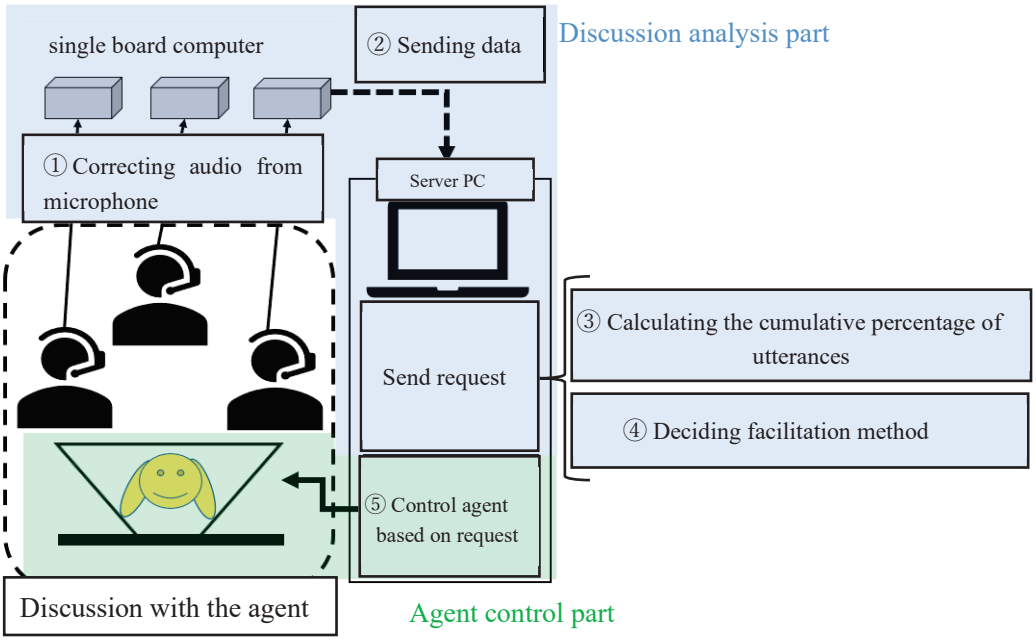

Figure 1. The overview of the facilitation system

3.2 Calculating the cumulative percentage of utterances

The cumulative percentage of utterances is the rate of each participant's speech when the total time of all participants' speech from the start of discussion to the time of the calculation is set to 100%. Silent periods are not included in the calculation of the percentage. For instance, if three participants speak for 2, 3, and 5 minutes respectively in a 10-minute discussion, the cumulative percentage of utterances is 20%, 30%, and 50%, respectively.

3.3 Criteria for agent facilitation

The holographic agent facilitates discussions when the system detects that a speech imbalance is occurring in a discussion. In general, when the number of participants in a discussion is n, if the cumulative percentage of utterances in all participants is 100/n%, it can be considered that there is no imbalance in the speech of each participant. However, it is unlikely that the cumulative speech rate of all the discussion participants coincides. Therefore, we set 100/n% $\pm$ (100/n - 100/(n+1))% as the acceptable range, and the situation in which there is a participant who is out of this acceptable range as the biased state. For example, for a three-person discussion, the acceptable range would be 25% to 41%.

The agent suppresses the speech of the participants whose cumulative percentage of utterances is higher than the acceptable range, and encourages the speech of the participants whose cumulative percentage of utterances is lower than the acceptable range. When the cumulative percentage of utterances of all participants is within the acceptable range, the agent does not approach them, but listens or observes them. Therefore, the following three facilitations are performed by the agent system. Decisions on agent behavior based on the cumulative percentage of utterances were made every minute.

- If there is one or more discussion participants whose cumulative percentage of utterances is lower than the acceptable range and there is no discussion participant whose cumulative percentage of utterances is higher than the acceptable range.

In this case, there is a imbalance in speech because there is a participant who does not speak much. Therefore, the agent asks the participant to "Why don’t you express some opinions?" or "Why don’t you explore the opinions so far?" with voice.

- If there is one or more discussion participants whose cumulative percentage of utterances is higher than the acceptable range and there is no discussion participant whose cumulative percentage of utterances is lower than the acceptable range.

In this case, there is a imbalance in speech because there is a participant who speaks much. Therefore, the agent asks the participant to "Why don't you ask others?" or "Why don't you explore other people's opinions?” with voice.

- If there is one or more discussion participants whose cumulative percentage of utterances is higher than the acceptable range and lower than the acceptable range.

In this case, there is a imbalance in speech because there are both a participant who speaks much and speaks little. In this case, the above two cases are alternated.

4. Experiment

An experiment was conducted to evaluate the effectiveness of the facilitation system. Each participant had two discussions, one is the experimental discussion using the system, and another is the control discussion without the system. The order of the two discussions was

random. Two discussion topics were set as "What is thoughtful consideration?" and “What is happiness?”. Discussion topics are based on a course of study in Japan (MEXT, 2020). These discussions were attended by three graduate and undergraduate students of a science and engineering university. Each discussion had three participants and lasted for 20 minutes.

After discussion, we conducted a questionnaire to evaluate the system. In the system evaluation questionnaire, participants were asked to describe how they felt the system facilitation. Figure 2 shows the discussion with the system.

Figure 2. A discussion with the agent

5. Results

5.1 RQ1: Can the facilitation method using the cumulative percentage of utterances throughout the discussion equalize the percentage of utterances?

We examined the effects of the facilitation system on equalization of speech from the viewpoint of the standard deviation of the cumulative percentage of utterances. This standard deviation represents the degree of speech imbalance among the participants. That is, if the standard deviation in the experimental discussion is smaller than the standard deviation in the control discussion, the system should promote equalization of speech among participants. Table 1 shows the standard deviation of the cumulative percentage of utterances in seven groups.

Table 1. *Standard deviation of the cumulative percentage of utterances in control discussion (without the system) and experimental discussion (with the system)*

	Standard deviation of the cumulative percentage of utterances	
Group No.	Control discussion	Experimental discussion
1	15.44	2.23
2	13.22	4.63
3	13.52	6.36
4	17.58	13.40
5	25.45	15.43
6	23.85	18.06
7	20.66	19.56

5.2 RQ2: If the method is effective (or not effective), how the system reduced (or increased) utterance imbalance?

From Table 1, the method should be effective to promote equalization speech among participants. However, the degree of mitigation of the speech imbalance by the facilitation system was different. Therefore, we divided the seven groups into two groups: a large effect

group (group 1-3) and a small effect group (group 4-7). Additionally, we examined the process of equalization in the large and small effect groups. Figure 3 shows the percentage of utterances per minute in the experimental discussion of Group 3 and Figure 4 shows that of Group 7. Group 3 had the highest number of the facilitation in the large effect group and Group 7 had the largest the standard deviation in the small effect group.

The percentage of utterances is recalculated every minute in Figure 3 and Figure 4. For example, Figure 3 shows that participant 1 spoke longer than other participants in the interval from 60 to 120 seconds.

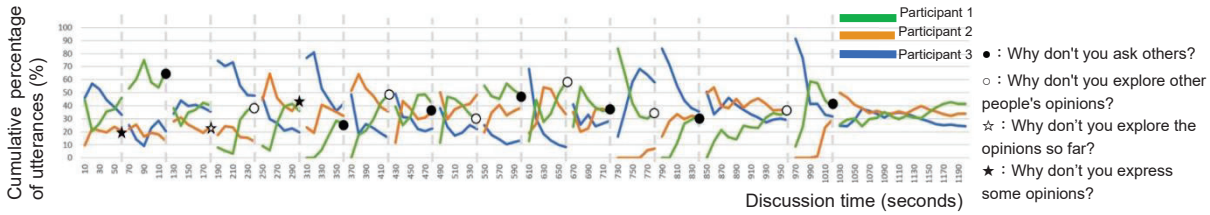

Figure 3. The cumulative percentage of utterances per minute in the experimental discussion of Group 3 in large effect group

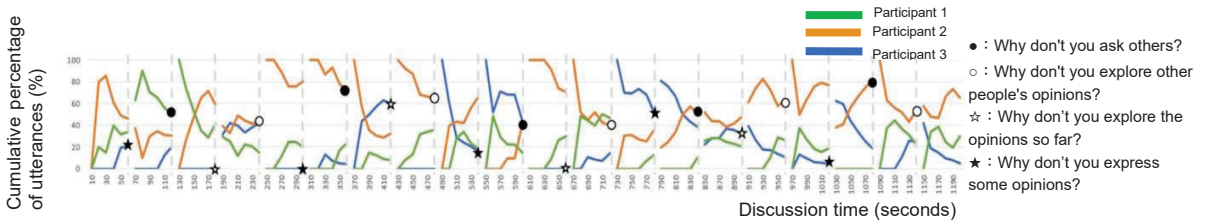

Figure 4. The cumulative percentage of utterances per minute in the experimental discussion of Group 7 in small effect group

6. Discussion

Table 1 shows standard deviation of the cumulative percentage of utterances decreased for all groups to a certain degree. Therefore, RQ1 is partially shown. In addition, Figure 3 and 4 suggest that turn-taking differs between the large and small effect groups. For example, each cumulative percentage of utterances per minute in Group 3 is equalized and cross many times after the instructions in both the first and second halves of the discussion. This means speaking turn rotated fast and equally in Group 3. On the other hand, each cumulative percentage of utterances per minute in Group 7 is not equalized and cross few times despite being facilitated by the agent system. Similar results were observed in the questionnaire. Participants in Group 3 answered that they were aware of speech imbalance due to the facilitation, while participants in Group 7 answered that they ignored it due to the difficulty of following the facilitation. Therefore, awareness of turn-taking is the key to answering RQ2: in order to equalize speech, it is necessary for participants to be aware of speech imbalance through facilitation and to correct it actively by turn-taking. These results imply the effectiveness of facilitation may be evaluated by observing the turn-taking after the facilitation.

7. Conclusion

In this paper, we proposed the facilitation system based on the cumulative percentage of utterances in discussions. Here, the experiment yields two important results: this system is contributed to promote equalization of speech among participants and turn-taking is a key to equalize cumulative percentage of utterances. Our study gives a quantitative perspective of the facilitation.

However, this study has some limitations. In this study, we mainly analyzed large effect group and small effect group from the graph of cumulative percentage of utterances. We need to further explore factors that may make the difference in the effectiveness of the facilitation system such as personality characteristic.

Acknowledgements

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References

Alavi, M. (1994). Computer-mediated collaborative learning: An empirical evaluation. *MIS quarterly*, 159-174.

Bachour, K., Kaplan, F., & Dillenbourg, P. (2010). An interactive table for supporting participation balance in face-to-face collaborative learning. *IEEE Transactions on Learning Technologies*, *3*(3), 203-213.

Bergstrom, T., & Karahalios, K. (2007, January). Conversation Clock: Visualizing audio patterns in co-located groups. In *2007 40th Annual Hawaii International Conference on System Sciences (HICSS'07)* (pp. 78-78). IEEE.

DeSanctis, G., & Gallupe, R. B. (1987). A foundation for the study of group decision support systems. *Management science*, *33*(5), 589-609.

DiMicco, J. M., Hollenbach, K. J., Pandolfo, A., & Bender, W. (2007). The impact of increased awareness while face-to-face. *Human–Computer Interaction*, *22*(1-2), 47-96.

Ishikawa, N., Okazawa, T., & Egi, H. (2019). DiAna-AD: dialog analysis for adjusting duration during face-to-face collaborative discussion. In *Collaboration Technologies and Social Computing: 25th International Conference, CRIWG+ CollabTech 2019, Kyoto, Japan, September 4–6, 2019, Proceedings 25* (pp. 212-221). Springer International Publishing.

Jermann, P., Soller, A., & Muehlenbrock, M. (2001). From mirroring to guiding: A review of the state of art technology for supporting collaborative learning. In *European Perspectives on Computer-Supported Collaborative Learning* (pp. 324-331).

Kim, T., Chang, A., Holland, L., & Pentland, A. S. (2008, November). Meeting mediator: enhancing group collaboration using sociometric feedback. In *Proceedings of the 2008 ACM conference on Computer supported cooperative work* (pp. 457-466).

Latané, B., Williams, K., & Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. *Journal of personality and social psychology*, *37*(6), 822.

MEXT (Ministry of Education, Culture, Sports, Science and Technology). (2020, October). English Translation of the Revised a Course of Study at Junior High Schools Revised in 29th year of the Heisei period (provisional translation). Retrieved from https://www.mext.go.jp/content/20201008-mxt_kyoiku02-000005242_1.pdf.

Miyake, N., Okita, S., & Rose, C. (2012). Robot facilitation as dynamic support for collaborative learning.

Praharaj, S., Scheffel, M., Drachsler, H., & Specht, M. (2019). Group Coach for Co-located Collaboration. In *Transforming Learning with Meaningful Technologies: 14th European Conference on Technology Enhanced Learning, EC-TEL 2019, Delft, The Netherlands, September 16–19, 2019, Proceedings 14* (pp. 732-736). Springer International Publishing.

Tausch, S., Hausen, D., Kosan, I., Raltchev, A., & Hussmann, H. (2014, October). Groupgarden: supporting brainstorming through a metaphorical group mirror on table or wall. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational* (pp. 541-550).