Annals of the Academy of Romanian Scientists
Series on Science and Technology of Information
ISSN 2066 - 8562 Volume **4**, Number **1**/**2011**

A DIALOGIC MODEL FOR ASSESSING THE COLLABORATION AND THE INVOLVEMENT OF CHAT PARTICIPANTS

Mihai DASCĂLU[1], Ștefan TRĂUȘAN-MATU[2],
Traian REBEDEA[3], Constantin DANIIL[4]

Rezumat. *O dată cu creșterea rapidă la nivel de utilizare și răspândire a tehnologiilor CSCL (Computer Supported Collaborative Learning), nevoia de a evalua automat contribuția și impactul replicilor și al participanților a devenit din ce în ce mai acută. Lăsând la o parte aspectul că evaluarea în sine este un proces consumator de timp, aceasta devine mai dificilă pe măsură ce în cadrul discuției sunt implicați mai mulți participanți și concomitent cu o întrețesere mai deasă a replicilor. În acest context propunem un sistem axat pe evaluarea implicării și a nivelului de colaborare al participanților în cadrul discuției. Adițional, o abordare clasică care combină prelucrarea limbajului natural cu analiza rețelelor sociale s-a demonstrat insuficientă pentru a obține o înțelegere profundă a discursului. Astfel, noi propunem un model bazat pe dialogism (Bakhtin) care surprinde și utilizează întrețeserea replicilor pentru a evalua colaborarea și nivelul de polifonie al întregului chat.*

Abstract. *With the rapid increase of use and spread of Computer Supported Collaborative Learning technologies, the need of automatically evaluating the contribution and the impact of each participant and utterance has increased substantially. Besides being a time consuming process, the evaluation of a discussion is even more difficult with the increase in number of participants and with the intertwining of utterances. In this context we propose a system devised for evaluating the involvement and the degree of collaboration of participants in chat conversations. Moreover, a traditional NLP (natural language processing) approach combined with Social Network Analysis proved insufficient for obtaining a deep understanding of the discourse. Hence, we propose a model based on Bakhtin's dialogism that captures and uses the intertwining of utterances in order to assess collaboration and polyphony within a chat conversation.*

Keywords: Bakhtin's dialogism, chat assessment, natural language processing, social network analysis

[1]As., MSc, Faculty of Automatic Control and Computers, University Politehnica of Bucharest, Bucharest, Romania, (mihai.dascalu@cs.pub.ro).
[2]Corresponding member of AOSR. Prof., PhD, Faculty of Automatic Control and Computers, University Politehnica of Bucharest, Bucharest, Romania, (stefan.trausan@cs.pub.ro).
[3]As., MSc, Faculty of Automatic Control and Computers, University Politehnica of Bucharest, Bucharest, Romania, (traian.rebedea@cs.pub.ro).
[4]Student, Faculty of Automatic Control and Computers, University Politehnica of Bucharest, Bucharest, Romania, (daniilconstantin@yahoo.com).

1. Introduction

Although instant messaging (chat) has been used for several years, the lack of sophisticated and accurate ways of analyzing and processing natural language has hindered the implementation of automatic analysis and feedback systems. In order to process text and conversations, several programs like DIGALO [6], CORDTRA [7] and TATIANA [5] were designed. Most of the previous programs use contingency or argumentation graphs and allow only annotations and visualization based on links added manually.

The program presented in this paper uses a polyphonic thread model [12] and provides detailed feedback to the user on both chat and forum discussions. The information provided by this system is derived from Bakhtin's dialogism theory [1, 2, 9], whereas the entire system is constructed on a CSCL model. Moreover, the approach successfully integrated social network analysis with NLP and polyphonic analysis.

2. The fundamental concepts of our system

The program analyzes chats based on 3 intertwined concepts, namely utterances, voices and echo. The core units of any discussion, *utterances* are segments of the discussion that differ in terms of the subject at hand. Separating utterances is a difficult process, as they can contain anything from a few words, to pages of text. Our analysis is based on Dong's perspective [4] that separates utterances based on the remarks of the participants: when a user expresses a different point of view or intervention, a new utterance is born.

Our system analyzes both the coherence and the meaning of each utterance by creating an *utterance graph* based on explicit (added by the participants) and implicit links (derived from the actual discussion). In this graph, a node is an utterance and the edges are expressed in terms of similarities between them projected on the discussion timeline. By using this graph, we are also able to determine the way utterances interact via their so-called inner-voices.

If utterances differ in terms of the subject of discussion, *voices* differ in terms of points of view or positions. A certain utterance may be developed and re-discussed several times during a conversation, thus creating a perspective or topic, hence a voice.

Both remarks of a single individual or of a group can constitute a single voice, thus creating generalized voices (similar opinions of a larger group of persons), internal voices (personal opinions) and external voices (opinions openly stated by individuals). Voices can be measured in different ways, regarding both their strength and frequency. A common phenomenon is ventriloquism, in which a certain voice is reemitted by another.

In order to obtain good collaboration between individuals, a conversation must become a true polyphony in the sense that multiple different voices harmoniously combine and focus on a specific topic. This process also allows us to make a psychological analysis of the participants.

Moreover, a discussion can also be divided into separated parts, each with a main voice from which a specific context can arise that merges all similar voices. As such, a voice, if repeated during a conversation, can exert influences upon others, therefore generating echoes within the discussion. An echo can either influence a single individual, thus being an individual echo, or a group of people, thus becoming a collective echo. As a conversation evolves and contexts begin to form, new voices arise, later to become echoes and further influencing the continuation of the discussion.

If we are to take into account all 3 previous concepts, we notice an effect that was both *retrospective and synergetic*, being based on merging voices from previous utterances and their echoes, and another *prospective effect* that showed how the echo of a voice can model the entire further discourse.

As such, a conclusion can be drawn, namely that users and voice inter-animation are the core of collaboration in a conversation. Our system aims to analyze the involvement and the inter-animation between users and voices within a conversation in a polyphonic manner. The results from a formal validation round highlight that the system provides very effective feedback for both teachers and students.

3. The conversation evaluation process

As mentioned before, the first and main step in the analysis of any discussion, weather it is a chat or otherwise, is the creation of the utterance graph, containing both explicit utterances, marked specifically by the users, and implicit ones that derive from the context of the conversation. In this graph, every utterance is a node. The nodes are connected by several edges, each with an assigned trust corresponding to the actual method of identification (repetition, co-reference, lexical chains) [8, 11].

As the chat advances, the orientation of edges corresponds to the timeline of the discussion and to the evolution of the conversation in time. The initial links are in the opposite direction and connect the current utterance to a previous one to which it is liked either implicitly or explicitly.

The process of evaluating an utterance is a challenging task. Therefore quantitative, qualitative and social aspects were considered when grading every utterance. These dimensions enabled us to evaluate the impact of a single utterance taken individually or within all corresponding discussion threads.

The first step in this analysis is to correct an utterance grammatically and orthographically, eliminating stop words and counting the remaining characters, thus obtaining the quantitative grade. In addition, in order to avoid the unnecessary repetition of certain words, the logarithm of the occurrences of each word is used instead.

The next step is to evaluate the similarity between the current utterance and the vector of the entire chat which syntheses the correlation with the overall discussion; furthermore, given the vector of a certain set of keywords chosen by the mentor as relevant subjects for the discussion, we can evaluate the similarity, therefore the coverage of those topics within each utterance. The qualitative mark combines these two aspects and provides a deep understanding of the importance of each utterance with regards to the entire discussion and to the predefined set of keywords.

Our semantic analysis is based on a vector space model from Latent Semantic Analysis [10] and similarity is computed by means of cosine measure. An interesting aspect is the visualization of this space, the links between concepts, depicted in Fig. 1:

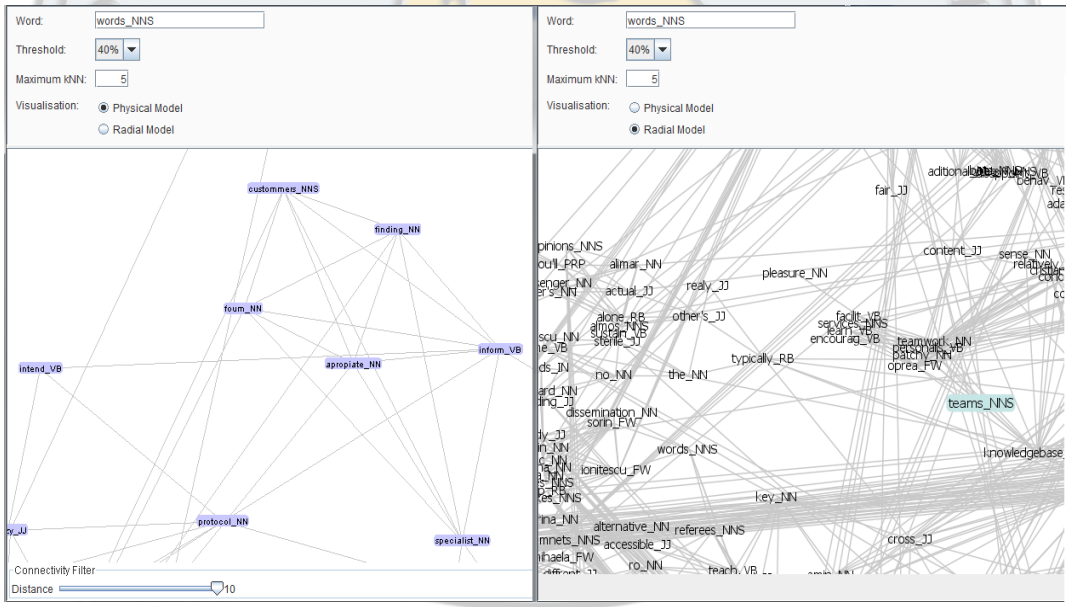

Fig. 1. Physical and radial view of the vector space model starting from a given word.

The final step in the assessment of each utterance represents the social analysis. In this step, we analyze the utterance graph using similar metrics to social network analysis, although centrality isn't very meaningful for such a conversation. Both previous perspectives are re-used here, the quantitative one for the number of links and the qualitative one by means of LSA similarity.

In our evaluation we currently use in and out-degree to assess the utterance graph, but we are planning to add other measure relevant to this specific structure of inter-twining utterances.

Based on the described algorithm, the mathematical formulas we use to grade each individual utterance are the following:

$$\text{mark(u)}= \left(\sum_{\text{remaining words}} length(stem) \times (1+\log(no\_occurences)) \right) \times \times emphasis(u) \times social(u) \quad (1)$$

$$emphasis(u) = Sim(u, whole\_document) \times Sim(u, predefined\_keywords) \quad (2)$$

$$social(u) = \prod_{\substack{\text{all social factors } f \\ (\text{quantitative and qualitative})}} (1+\log(f(u)) \quad (3)$$

4. The assessment of collaboration in a chat conversation

Being essential to every successful conversation, collaboration in a chat is analyzed from multiple perspectives. We take into account social cohesion and collaboration, the quantitative mark and gain based collaboration that we will explain shortly.

Based on the previous analysis, we can assume that in any type of conversation an essential presumption is generally applicable: the more the speakers have rather similar involvement and knowledge relative to the number of individual interchangeable utterances and the topics taken into account and analyzed with LSA as support, the more efficient the level of collaboration will be, as they will all be on the same ground. This aids to the social cohesion and collaboration analysis, which is based on social network analysis.

Since this analysis is however different from standard social network analysis, in order to uniformly spread the measure for each individually considered factor, a variation coefficient for each metric is necessary. The final results are computed as the difference between the initial total and the average value of all partial results, obtaining better impact and cohesion with the increase of the collaboration between individuals. There are the limitations of the current state of the project, but future upgrade will include weighted influences for each factor of the collaboration evaluation, depending on the status of the speaker (for example in-degree remarks should be more relevant to the current speaker).

What is by far the most direct approach for evaluation of chat discussions is the use of explicit and implicit links. We can determine the degree of collaboration

from their number, averaged using a trust coefficient assigned to them. As a subject is discussed by multiple users, each reference to previous utterances increases the degree of collaboration between speakers, thus proving that the analysis of linked utterances from different speakers is efficient.

Based on this principle, we can compute a quantitative collaboration grade:

$$\text{quantitative collaboration} = \frac{\sum_{\substack{\text{all links } l \\ \text{with different speakers}}} \text{trust}(l)}{\text{total number of links (implicit/explicit)}} \quad (4)$$

where trust(l) is the assigned trust for an implicit or explicit link (for example, in the case of direct repetition this value is set to 1); for all explicit links, trust is set to 1.

In any conversation, we can build personal and collaborative knowledge depending on whether we consider knowledge to be defined through individual study and experiences or to have a collective origin. From these perspectives, we derived the concept of gain based collaboration [3]. Gain can be either personal, in which connected utterances have the same speaker, or collaborative, in which information is generated by future involvement in a already existing discussion thread. Both individual and collective gains can be easily connected to the personal and collective echoes throughout a conversation interweaving inner dialogue (based on individual voices) with explicit dialogue (based on inter-connected utterances).

Based on the previous statements, the following formulas are used for evaluating gain throughout the conversation:

$$\text{gain}(u) = \text{personal gain}(u) + \text{collaborative gain}(u) \quad (5)$$

$$\text{personal gain}(u) = \sum_{\substack{\text{link } l \text{ between } u \text{ and } v, \\ v \text{ is an earlier utterance and} \\ u \text{ and } v \text{ have same speaker}}} ((\text{mark}(v)+\text{gain}(v))*\text{similarity}(u,v)*\text{trust}(l)) \quad (6)$$

$$\text{collaborative gain}(u) = \sum_{\substack{\text{link } l \text{ between } u \text{ and } v, \\ v \text{ is an earlier utterance and} \\ u \text{ and } v \text{ have different speakers}}} ((\text{mark}(v)+\text{gain}(v))*\text{similarity}(u,v)*\text{trust}(l)) \quad (7)$$

We can thusly identify numerous sets of interconnected elements: personal gain – personal knowledge building – individual echoes – inner dialogue and collaborative gain - collaborative knowledge building – collective echoes – explicit dialogue which are the cornerstone for analyzing collaboration in any conversation.

From the previous formals, we can derive 2 metrics for analyzing collaboration in a chat conversation:

- Formula (8) is used for estimating the percentage of overall utterances' importance/marks relatively to information built / transferred in a collaborative manner:

$$\text{mark based collab}= \frac{\sum_{\text{all utterances u}} \text{collaborative gain(u)}}{\sum_{\text{all utterances u}} \text{mark(u)}} \tag{8}$$

- Formula (9) is used for assessing collaboration relatively to the overall gain (practically excluding inner build):

$$\text{gain based collab}= \frac{\sum_{\text{all utterances u}} \text{collaborative gain(u)}}{\sum_{\text{all utterances u}} \text{gain(u)}} \tag{9}$$

Based on these factors, we can assess the overall collaboration as a product of the previous metrics:

$$\text{overall collaboration} = \text{social cohesion} \times \text{quantitative} \times \text{gain based} \times \text{mark based} \tag{10}$$

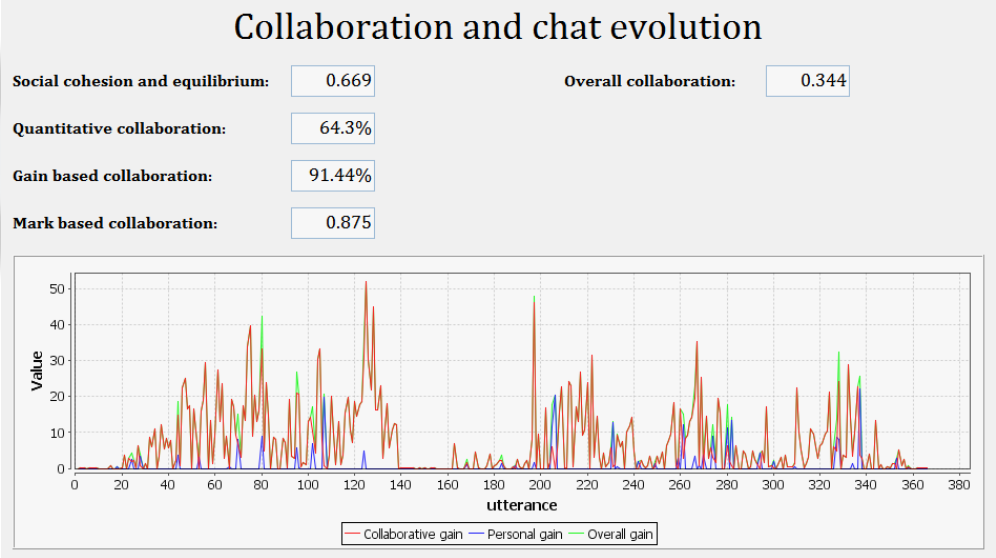

Fig. 2. Collaboration assessment and chat evolution visualization.

5. Conclusions

Due to the multiple limitations of the NLP paradigm, currently chat and other similar conversation types cannot be suitably analyzed in terms of inter-collaboration and user participation due to the complex connections that need to be considered. The most suitable model for doing such an analysis would be the polyphonic one, which is founded on Bakhtin's principles of dialogism and polyphony, as such a model could correctly evaluate the degree of collaboration in a conversation.

Our system is based on such a model and analyzes CSCL chats with the purpose of accurately grading the involvement and knowledge of users during a conversation. Our analysis uses an utterance graph as its main fundament and integrates several relevant metrics and technologies enabling a deep understanding of the discussion.

Acknowledgment

The research presented in this paper was partially performed under the FP7 EU STREP project LTfLL (http://www.ltfll-project.org/).

REFERENCES

[1] M. M. Bakhtin, *The Dialogic Imagination: Four Essays* (University of Texas Press, Austin, 1981).

[2] M. M. Bakhtin, *Problems of Dostoevsky's poetics* (University of Minnesota Press, Minneapolis, 1993).

[3] M. Dascalu, T. Rebedea, S. Trausan-Matu, *A deep insight in chat analysis: Collaboration, Evolution and evaluation, summarization and search* (Proc.of the 14th Int. Conf. on Artificial Intelligence: Methodology, Systems, Applications (AIMSA 2010), Springer, Lecture Notes in Computer Science), 6304.

[4] A. Dong, *Concept formation as knowledge accumulation: A computational linguistics study* (Artif. Intell. Eng. Des. Anal. Manuf. **20**, 2006) pp. 35-53.

[5] Dyke, G., Lund, K., & Girardot, J.-J. (2009). Tatiana: an environment to support the CSCL analysis process. *Proceedings of Computer Support for Collaborative Learning*, 58–67.

[6] Harrer, A., Hever, R., & Ziebarth, S. (2007). Empowering researchers to detect interaction patterns in e-collaboration. *Frontiers in Artificial Intelligence and Applications*; Vol. **158**, 503–510.

[7] Hmelo-Silver, C. E., Chernobilsky, E`., & Masto, O. (2006). Representations for Analyzing Tool-mediated Collaborative Learning. *Proceedings of ICLS* 2006, New Brunswick.

[8] D. Jurafsky and J. Martin, *Speech and Language Processing. An Introduction to Natural Language Processing* (Computational Linguistics, and Speech Recognition. Second Edition, Pearson Prentice Hall, 2009).

[9] T. Koschmann, *Toward a dialogic theory of learning: Bakhtin's contribution to understanding learning in settings of collaboration* (C. Hoadley & J. Roschelle (Eds.), Proceedings of the Computer Support for Collaborative Learning 1999 Conference. Philadelphia, PA: Laurence Erlbaum Associates, 1999).

[10] Th.K. Landauer, P.W. Foltz, and D. Laham, *An introduction to latent semantic analysis*. (Discourse Processes, University of Colorado, 1998), pp. 259-284.

[11] C. Manning and H. Schütze, *Foundations of statistical Natural Language Processing* (MIT Press, Cambridge Mass., 1999).

[12] Trausan-Matu, S., Stahl, G., Sarmiento, J. (2007). Supporting Polyphonic Collaborative Learning, *E-service Journal*, Vol. **6**, no. 1, Indiana University Press, pp. 58-74.