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.

Visualization of polyphonic voices inter-animation in CSCL chats

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Abstract. Instant messenger (chat) is one of the means of Computer Supported Collaborative Learning, which may foster students' inter-animation towards joint knowledge construction. However, the analysis and grading of such chats is an extremely time-consuming activity, therefore (semi-)automatic analytics tools are needed. Discourse threads in a chat may become very complex and intertwined, becoming like voices in a polyphonic musical piece. Starting from the polyphonic model, several learning analytics systems were implemented, in which voices and their inter-animation visualization have a central role. This paper tries to analyze the classes of implemented visualizations, from an interdisciplinary perspective.

Keywords: polyphony, dialogism, CSCL, chats, inter-animation, visualization

1. Introduction

Chats are a way of collaborative learning anytime, anywhere, being also well suited for Massive Open Online Course (MOOCs). However, their analysis and grading are very time consuming (Trausan-Matu, 2010b) and, therefore, computer-support tools are needed. In this aim, a model and analysis method were introduced (Trausan-Matu, 2010a; Trausan-Matu, 2014; Trausan-Matu, Dascalu and Rebedea, 2014). A series of implementations were developed based on this model (Trausan-Matu, Rebedea et al., 2007; Trausan-Matu, Dascalu and Rebedea, 2014; Dascalu et al., 2013), all of them including visualizations as a major way of providing insights on the collaboration process.

The major phenomenon associated to a good collaboration is inter-animation. Unfortunately, there are not simple ways to automatically identify inter-animation. In this aim, the visualization of several factors may help a human analyst.

This paper tries to introduce a theoretical background in order to do a systematization of the visualization types that may be used for inter-animation detection. Exemplification using *PolyCAFe* (Trausan-Matu, Dascalu and Rebedea, 2014) and *ReaderBench* (Dascalu et al., 2013) are included.

The paper continues with a section that briefly presents the main ideas of polyphonic inter-animation in CSCL chats. The third section discusses about basic concepts of visualization, about specific aspects of chat visualization, and presents some systems for chat visualization. The last section before conclusions is analysing classes of visualizations useful for identifying inter-animation, with comparative examples of two opposite chats in the inter-animation sense.

2. Polyphonic inter-animation in CSCL chats

A polyphonic framework is characterized by a set of voices, each of them having individuality but that inter-animate through dissonances and consonances, eventualy a coherent achievement being obtained (Trausan-Matu, Stahl & Sarmiento, 2007). The concept of 'voice' should be generalized from the physical, auditive dimension towards including also inner speech, alien, or implicit presences in dialogues, in an extended sense. For example, voices may be concepts that become noticeable in a discussion, as artifacts, from words' repetitions (Trausan-Matu, 2013).The basic elements considered in the polyphonic model and analysis method are the participants, the utterances, their interrelations, the voices, inter-animation patterns (Trausan-Matu, Dascalu and Rebedea, 2014), and discourse structuring towards coherence.

Several opinions (Koschmann, 1999; Wegerif, 2006; Trausan-Matu, Stahl & Sarmiento, 2007), consider *inter-animation* (Bakhtin, 1981) as an important phenomenon that appears in a successful natural language based collaboration. Holquist (1981) associates also *inter-illumination* to inter-animation, in a glossary of Bakhtin's concepts. Inter-illumination may be considered, in the CSCL perspective, as the reciprocal influence of voices in the process of knowledge building, of the illumination that give birth to the solution to a debated problem.

The steps of the polyphonic analysis method are (Trausan-Matu, Dascalu & Rebedea, 2014):

1. Utterances are delimited.
2. In addition to the explicitly stated links (for example, by using the facility of the VMT and ConcerChat systems, Holmer et al., 2006), implicit ones are identified between utterances – repetitions of words and phrases, adjacency pairs, justification links, co-references, etc. – and a graph of utterances may be constructed.
3. Identification of voices; threads of re-voicings (echoes), should be detected starting from repeated important words.
4. Identification of inter-animation patterns among voices.
5. Analyzing different aspects of discourse building: meaning making, identification of artifacts in problem solving, investigating pivotal moments, rhythm, collaboration regions, assessing learners' participation and the collaboration of the team as a whole.

In addition to them, time and context sould be considered. Time is an essential ingredient, in different perspectives, as sequences of events (e.g., utterances), intervals (e.g., pauses and duration of utterances), synchronization, repetitions, and rhythm.

Context is composed from a general one and a sequence of instants ones. The former includes dictionaries, concepts, ontologies, and corpora used for machine learning and other statistical processing. The instant context is particular to each chat, it changes permanently, with each utterance, and includes previously discussed utterances, words, phrases, and concepts. Instant contexts and time are very important in the inter-animation process.

Inter-animation is based on the repetition of concepts and other discourse structures. Concepts in chats may be classified in several groups. First of all, there are concepts from the discourse domain. These concepts may be introduced in an ontology or extracted via statistical methods like Latent Semantic Analysis (LSA, Jurafsky & Martin, 1999) and Latent Dirichlet

Allocation (LDA, Blei et al., 2003). Among concepts, in the both cases, similarity metrics may be calculated. Another class of concepts are those imposed as theme of discussion and a third class is that of the concepts that emerge from a conversation. For any concept a word or a phrase is associated.

For the illustration of various visualizations for detection of inter-animation in Section four, we focused on two chat conversations, antagonistic in terms of participants' active involvement and inter-animation, selected from a corpus of more than 100 chats that took place in our university (Trăusan-Matu, Dascălu, Rebedea & Gartner, 2010). As it can be clearly observed from Table 1, the second conversation lasted longer, had more than 50% additional utterances, and the rater's participation and collaboration scores were higher.

Table 1. Comparative statistics for the two selected conversations

Conversation	**Chat 1**	**Chat 2**
Contributions	190	297
Participants	4	4
Duration (hours)	1.00	1.50
Initial number of raters	35	30
Overall participation score (AVG)	7.29	8.03
Overall participation score (SD)	1.32	1.22
Overall collaboration score (AVG)	6.86	7.45
Overall collaboration score (SD)	1.86	1.75

Within each conversation, Computer Science undergraduate students undergoing the Human-Computer Interaction course debated on the advantages and disadvantages of CSCL technologies (e.g., chat, blog, wiki, and forum). Each conversation involved four participants and each member first discussed on a previously assigned technology, being its "advocate", later on proposing an integrated alternative that encompassed the previously presented advantages. Afterwards, thirty plus students were asked to manually annotate the conversations, grading the entire conversation on a 1-10 scale in terms of participation and, separately, collaboration. We opted to distribute the evaluation of each conversation due to the high amount of time required to manually assess a single discussion (on average, users reported 1.5 to 4 hours for a deep understanding) (Trausan-Matu, 2010b). Afterwards, raters with no variance or with a correlation lower than 0.3 in terms of intra-class correlations (ICC) with the other evaluator were disregarded. Most weak relationships reflected, in most cases, erroneous or superficial evaluations.

3. Visualization

A good visualization is an effective way for easing the analysis of complex systems. Visualization may be considered from several perspectives: semiotics, esthetics, physiology, psychology, immagery, etc.

Bertin (1967) considered that visualization may be done in several main ways: diagrams, networks, maps, and symbolic representations. He also identified several retinal variables, as ways of using visual discriminations (Bertin, 1967):

1. position – different locations in space;
2. size - changes in length, area, or repetition;
3. shape;
4. value – differences from light to dark;
5. color;
6. orientation - changes in alignment;
7. texture.

Starting from this classification, we will characterise visualizations by indicating which variables they include by appending to the letter ‘B’ (from “Bertin”) the coresponding numbers. For example, a visualization that includes position, size, shape and color is coded as B1235. Each of the above variables may be variations of three types of elements: points, lines and areas (Bertin, 1967).

Chats are usually visualized in a textual/tabular way, each utterance being represented on one line, containing the text of the utterance, the nickname of the participant that emitted the utterance and, sometimes, the time stamp, the number of the utterance and, if available the previous referenced utterances (some chat environments, like the VMT one, Stahl, 2009), offer the possibility that the participants indicate explicitly what utterance they refer to). On the tabular representation some additional visualizations may be used, like colored markings and connecting lines. For example, in Figure 1, a B135 visualization indicates with colored rectangles the repetitions of some keywords. The color and shape of the lines differentiate if they link threads of repeated words (black straight line segments) or utterances (light blue curly lines). Indented representations are also sometimes used, reflecting the referencing links among utterances.

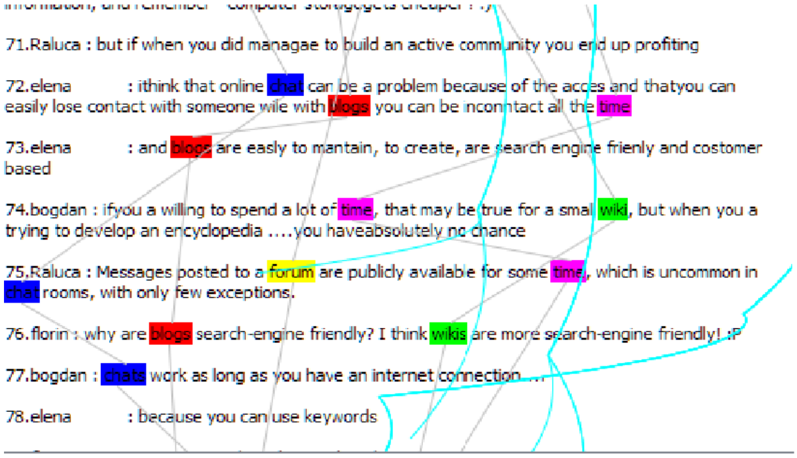


Figure 1. Chat fragment with two superimposed networks

Several systems for advanced graphical chat visualizations were developed. *Coterie* (Spiegel, 2001) is a system for the real time visualization of the activity of the participants in a chat and of the structure of the discussion. Each participant is represented by a different colored oval aligned to the bottom of the image, varying in size and centrality according to the length of their utterances and, respectively, to the number of contributions (B1245). When a participant emits an utterance, the oval comes brighter and bounces.

Coterie tries to identify conversation threads of utterances starting from repeated words and phrases. The last four utterances are shown on the screen grouped in conversations and with the color of the participant that emitted them. It is also trying to visualize the cohesion of the conversation, that means if the participants are maintaining a common topic (Spiegel, 2001).

ChatCircles (Viégas & Donath, 1999) is another chat visualization system. Each user is represented by a circle with a different color. Each utterance is shown in this circle when emitted. The size of the circle reflects the number of utterances emitted by the associated user. The positioning of the circles reflect the relative positioning of participants in the conversations (B125). A History View is also provided, in which each user has a vertical line on which her utterances are showed as line segments with a length proportional to their size, in a bottom-up time sequencing.

In *PeopleGarden* (Xiong & Donath, 1999), a B235 system, participation is illustrated by a flower metaphor. The height of the stem reflects the degree of participation. Each petal is an utterance, a red one for a posting and a blue one for a reply.

The above-mentioned applications aim at displaying groupings of participants, the degree of their participation and cohesion in a chat in real time. They focus mainly on visualizing the transversal, instant dimension and less the longitudinal, temporal variation dimension of the conversations, excepting maybe *Coterie*, which uses heuristics to separate different conversation threads. However, *Coterie* does not take into account the inter-animation patterns that may occur among discussion threads, one of the important features of a polyphonic perspective (Trausan-Matu, Stahl & Sarmiento, 2007).

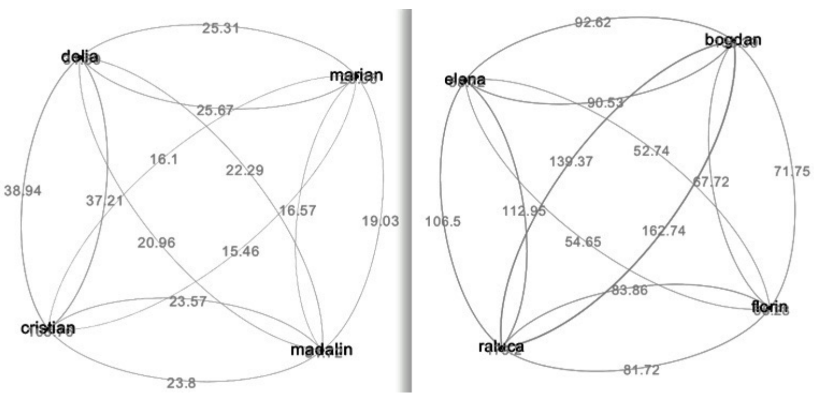
4. Visualization of polyphonic voices inter-animation

As discussed above, all the mentioned visualization systems do not focus on providing a mean for the identification of polyphony, which we consider essential for a good collaboration (Trausan-Matu, 2010a). A polyphonic analysis should consider, in the same time, the individual and collaborative aspects, the transversal and longitudinal dimensions, and the associated inter-animation patterns (Trausan-Matu, 2010a; Trausan-Matu, Stahl & Sarmiento, 2007).

As compared to participation, the structuring of the conversation or other features, considered by the systems discussed in the previous section, inter-animation is not easy to measure or detect automatically, in order to be directly visualized. Therefore, several indicators of inter-animation should be considered and visualized. Such indicators may be classified in three groups: a) the degree in which participants co-participate to the exchange of utterances, b) the content of the utterances, and c) the structure of discourse. Starting from these indicators, an analyst may infer where inter-animation occurs. Numerical estimations of inter-animation and knowledge-building may also be computed.

The degree in which participants co-participate to the exchange of utterances may be visualized either: a1) globally, or a2) in a temporal sequence.

a1) A common solution to reflect the degree of contribution of a participant is the size of a circle or other shape associated to him/her, as in the systems discussed in the previous section. However, for the co-participation, not the individual contribution is the most important, but the influences from the utterances of one participant to those of another participant should be considered. Therefore, rather a network would be constructed and displayed, containing participants as nodes and the arcs corresponding to the situations when at least one link exists between the utterances of the participants associated to the terminal nodes of the arc. Because such a network is in general a total graph, an useful information is the weight on links that reflects the number of links or another, more complex metric between utterances, for example, in *ReaderBench* relying on utterance scores that reflect each contribution's relevance with regards to the overall discussion and on the semantic similarity between utterances, measured via cohesion. Consequently, in Figure 2 higher weights in the second case indicate a probably higher inter-animation.



(1) (2)

Figure 2. Comparative view of the interaction graphs between participants in *ReaderBench*

a2) The global representation cannot give information about intervals (zones) of good inter-animation. Consequently, a visualization considering the time axis is needed. For representing co-participation in a temporal sequence a network representation may also be used, in which utterances are nodes and arcs are implicit or explicit links among them. Nodes are displayed aligned to a horizontal time axis, corresponding to the time stamp of each utterance. A vertical axis is used for distinguishing the participants for each utterance (see Figure 3).

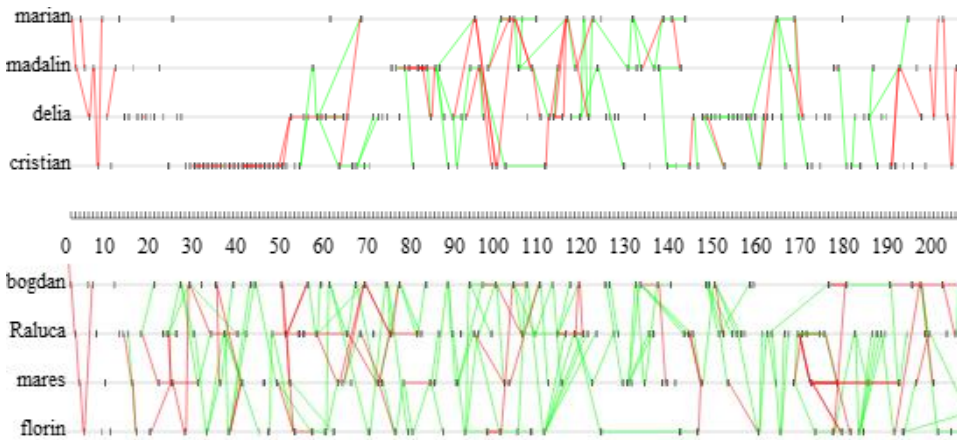


Figure 3. Comparative view of the network of explicit (red) and implicit (green) arcs among utterances. Obviously in the bottom case inter-animation is probably considerably higher. The visualization (type B135) was done with the *PolyCAFe* system

An alternative visualization, in terms of time evolution is using the cohesion graph (Trausan-Matu et al., 2012) which highlights both explicit links added by users in the *ConcertChat* interface (Holmer et al., 2006) and implicit links identified as being highly cohesive by the *ReaderBench* system (Dascalu et al., 2013). Also in this case the visualization shows that for the second conversation the network is denser (see Figure 4).

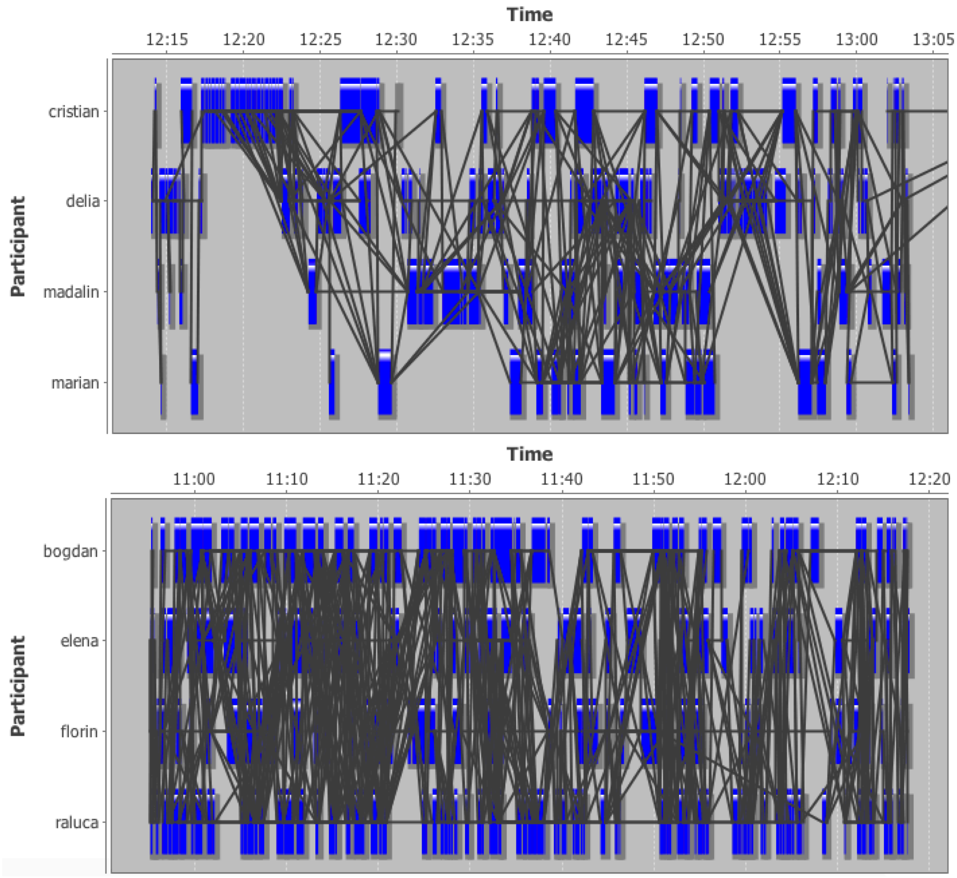


Figure 4. Comparative view of the conversation graphs in *ReaderBench*. In addition to the *PolyCAFe* system, more implicit links are detected considering cohesion among utterances

Also, a notable fact is that there are monologue zones in the first conversation, or areas in which only two participants collaborated; this is not the case for chat two in which we have a dense inter-twining between most conversation participants.

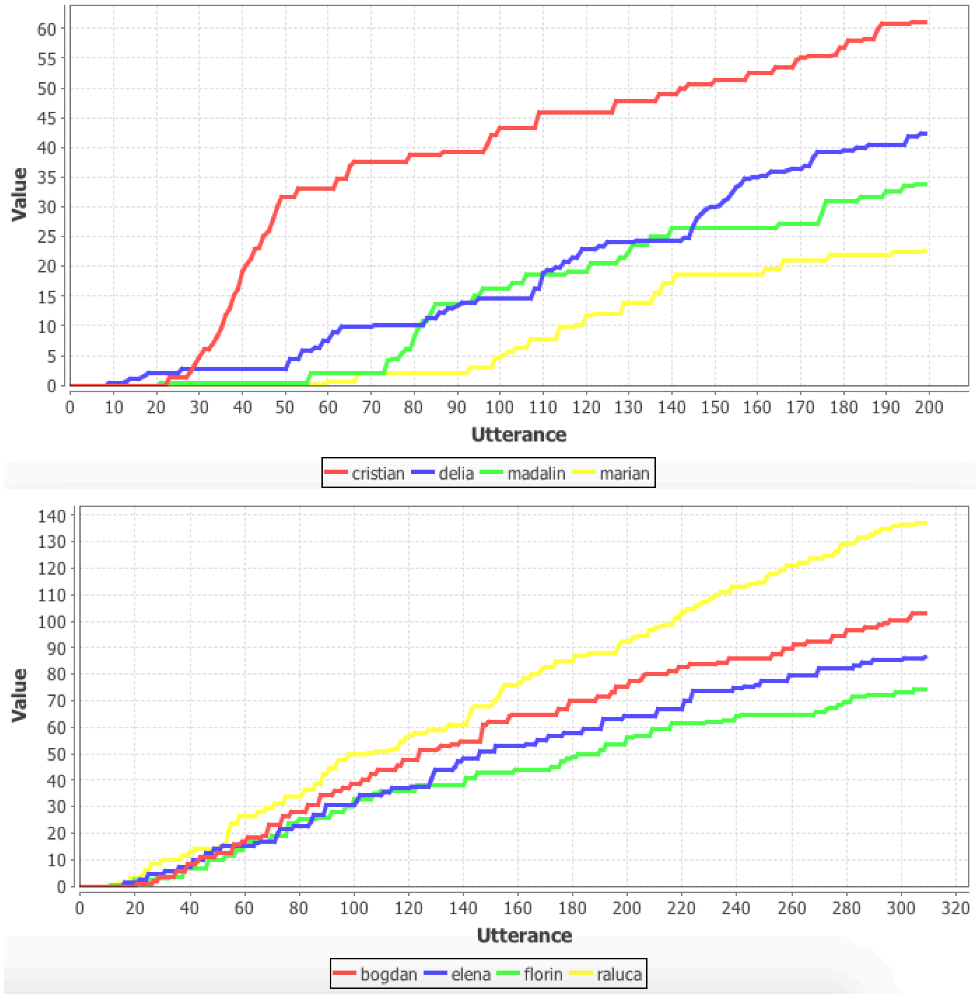


Figure 5. Comparative view of the evolution of contributions of participants

Another time-based visualization is done in *ReaderBench* by computing and displaying an additive contribution of each participant to the discussion. Inter-animation is probably higher when the diagrams of the participants are not very different, showing an equilibrated participation, as it is the case in the second chat in Figure 5.

(1)

(2)

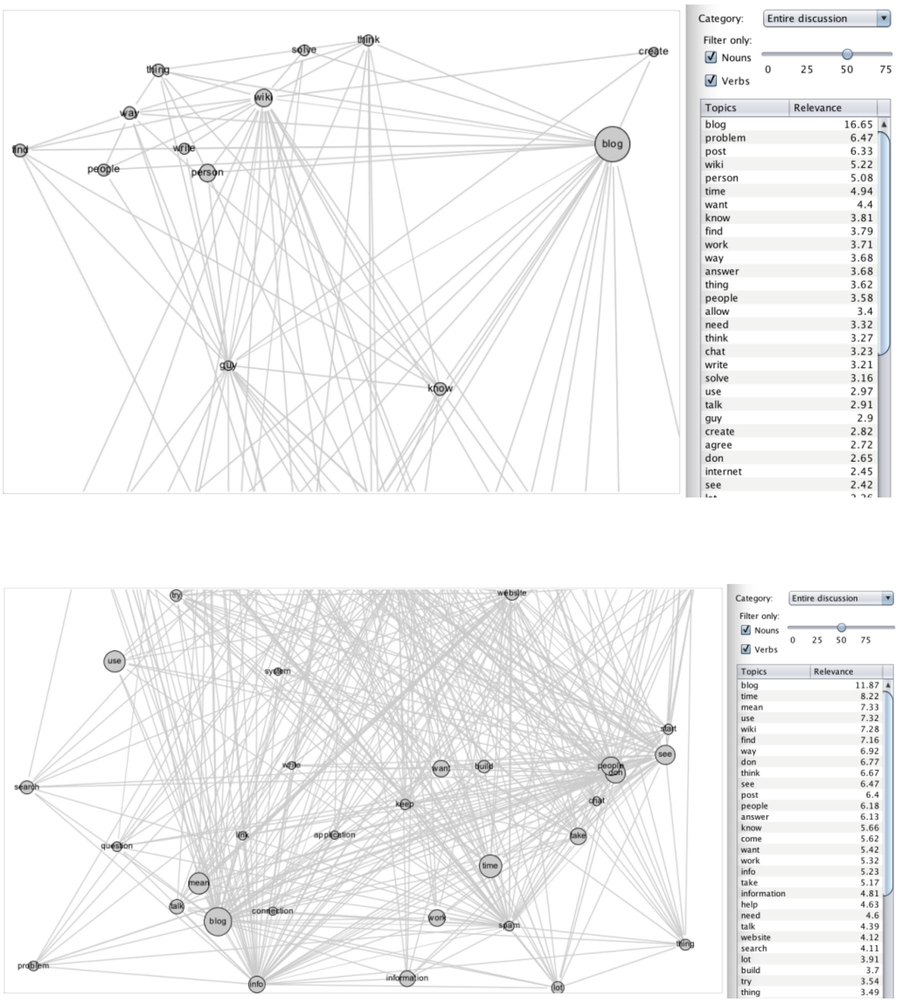


Figure 6. Comparative view of concept maps for the entire conversation.

b) The content of the utterances is a very important indicator of inter-animation, in conjunction to co-participation. In order to emphasize the different content of the conversations, Fig.6 introduces the concept maps that are generated based on the keywords of each conversation and the semantic similarities between words (Dascalu, Trausan-Matu & Dessus, 2013). Chat 1 is dominated by the "blog" concept, whereas chat 2 has denser associations between more semantically related keywords.

Similarly, when we look at the most relevant voices that span throughout each conversation (Dascalu et al., 2015), it is clear that the second conversation is more informative, makes use of more relevant concepts and has a wider overall coverage (see Figure 6).

c) Discourse structure is probably the most important indicator of inter-animation. Repetition of words and phrases and lexical chains, together with cue-phrases that suggest the presence of inter-animation patterns should be detected and visualized. A network may be build similarly to that of (a2), but having as nodes utterances containing keywords or cue-phrases and as arcs links corresponding to repetitions, lexical chains or other discourse relations (see Figure 7).

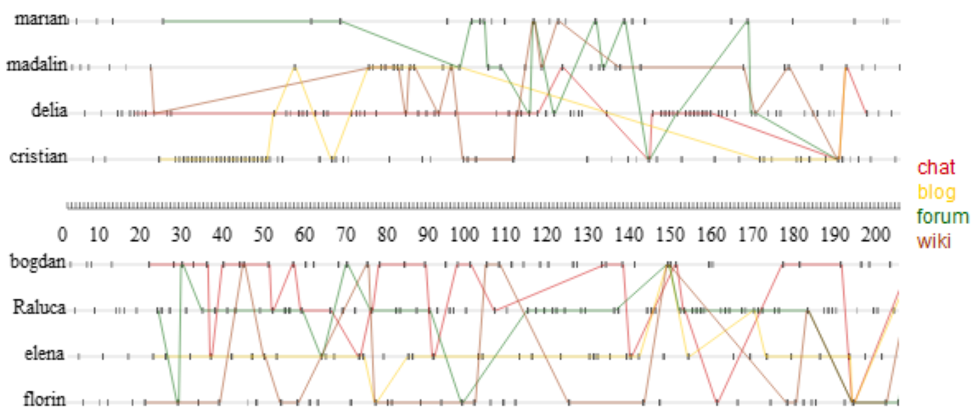


Figure 7. Networks of repeated keywords displayed with *PolyCAFe*

An alternative to this visualization is to superimpose the network of words (and maybe utterances) as nodes and links as arcs (including maybe also explicit and implicit links) to the textual (tabular) representation of a chat (see Figure 1). Instead of putting participants on the vertical axis and using colors for keywords, another visualization, a map type (also B135 as the previous two) puts topics detected by LDA on the vertical axis and colors for participants (see Figure 8).

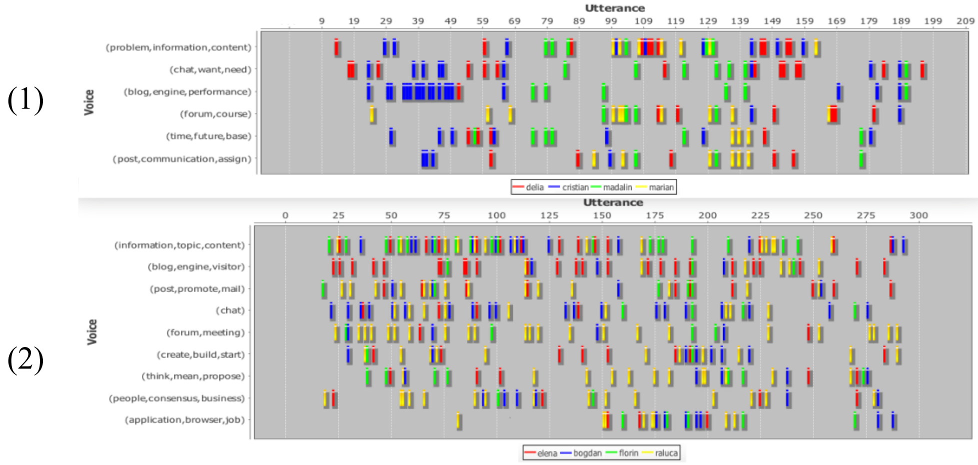
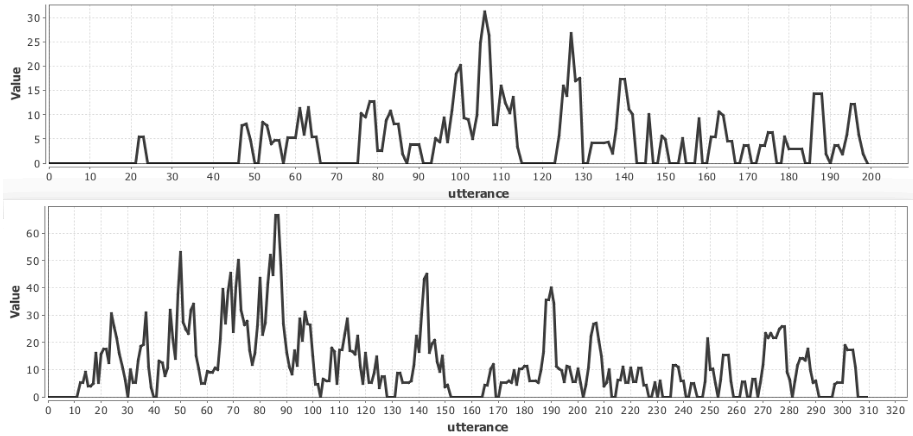


Figure 8. Comparative maps of the topics/participants distributions

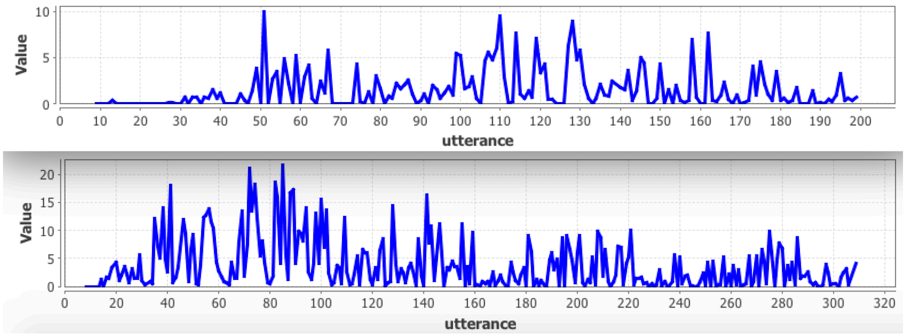
Using automated models of assessing collaboration – voice pointwise mutual information (Dascalu, Trausan-Matu, Dessus & McNamara, 2015) (see Figure 9) and social knowledge-building based on cohesion (Dascalu et al., 2015) (see Figure 10), numerical values may be computed for inter-animation and knowledge building. These diagrams emphasize that participants from the second conversation collaborated more one with another (higher overall scores) and there are fewer regions with a borderline collaboration score (i.e., monologue of one participant).



(1)

(2)

Figure 9. Comparative view of the voice inter-animation



(1)

(2)

Figure 10. Comparative view of the social knowledge-building models

5. Conclusions

Overall, the presented visualizations in the previous section were designed to enable a deep understanding of the interactions between participants and their involvement in the ongoing conversation based on the covered topics. This also enables the creation of different perspectives on participants' degree of collaboration considering longitudinal and transversal dimensions, as well as numerical factors of analysis. All these are indicators of inter-animation and polyphony, aspects not considered in other systems (some of them briefly presented in Section three). The exemplifications showed that visualizations provided in *PolyCAFe* and *ReaderBench* can be used as a starting point for judging the inter-animation in chats.

However, inter-animation, as the basic ingredient of a successful collaboration is still hard to identify. It should need to recognize argumentative and justification links, rhetorical schemas and inter-animation patterns (Trausan-Matu, Stahl & Sarmiento, 2007). For all these discourse structures specific visualizations have to be further designed and implemented.

Acknowledgments

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