Supporting Polyphonic Collaborative Learning[1]

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ABSTRACT

The article proposes a theory based on music polyphony, which helps to understand how learners inter-animate when they participate in collaborative chats for problem solving. In polyphony, different voices jointly construct a melody (story, or solution) enabling other voices to adopt differential positions and to identify dissonances (unsound, rickety stories or solutions). The proposed theory starts from ideas of Mikhail Bakhtin, and identifies in chats several classes of patterns of inter-animation along longitudinal and transversal dimensions, similarly to musical polyphonic contrapunctus. The article also describes implemented software tools, which facilitate the visualization of the threads in a chat and the influence that an utterance has on the subsequent ones. Such tools help both teachers and learners to evaluate and enhance the learning process. By supporting polyphonic structuring, the dialogue in learning chats becomes a kind of a "thinking device."

Keywords: *Computer-supported collaborative learning, polyphony, chat summarization, inter-animation, discourse analysis*

INTRODUCTION

In recent years, in the context of the intensive use of chat conferencing, discussion forums, and other Internet-based collaboration tools, Computer Supported Collaborative

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Learning (CSCL) became an alternative or supplement to classical learning. As a conceptual basis for work under the CSCL paradigm, Koshmann (1999) proposed Mikhail Bakhtin's dialogism (Bakhtin, 1981, 1984), emphasizing polyphony and multivocality as key features of this theory. Wegerif (2005) also proposes dialogism as an important paradigm, which can be used for developing tools for teaching thinking skills. However, until now, very few investigations and developments were performed on how these ideas could effectively be used for the analysis of CSCL dialogs and for the implementation of supporting tools. The research presented in this article is trying exactly to fulfill this lack. Therefore, it will investigate how Bakhtin's theory of polyphony and inter-animation can explain some phenomena that appear in CSCL chat conversations and how this theory can be used for the analysis and the support of collaborative learning chat conversations.

In polyphony, a number of voices jointly construct a harmonious musical piece, generating variations on one or several themes. They have to avoid or solve dissonances, even if they are playing several themes or theme variations, and even if sometimes they situate themselves on differential positions.

Bakhtin considers that multiple voices are present also in texts and, sometimes (e.g., in Dostoevsky's novels) they constitute a polyphonic framework (Bakhtin, 1984). Extrapolating this idea, we observed that voices, following polyphonic inter-animation patterns, occur also in dialogs, in general, and in Internet instant messenger's chats, in particular. A polyphonic collaboration involves several voices that play several themes and their variations in a game of sequential succession and differential positions. The existence of different voices emphasizes "dissonances," unsound, rickety stories or solutions. This polyphonic game may eventually make clear the correct, sound solution, as will be shown in an example of a CSCL chat for solving a mathematics problem.

The above ideas are exemplified with chat excerpts for collaborative learning in two domains: mathematics problem solving, investigated in the Virtual Math Temas (VMT) project at Drexel University, and human-computer interaction at "Politehnica" University of Bucharest (PUB). Inter-animation patterns were discovered in two dimensions: longitudinal (chronologically sequential) and vertical, towards two opposite trends: unity vs. difference. The visualization facilities of the "Polyphony" environment for collaborative learning, based on the polyphonic inter-animation principles and developed at PUB, are also presented.

The article continues by introducing some ideas about CSCL, discourse, the dialogic theory of Mikhail Bakhtin, and polyphony. The following section analyzes the polyphonic welding of longitudinal-vertical unity-difference dimensions in CSCL chats, and classifies types of inter-animation patterns. Visualization tools that support the polyphonic inter-animation are presented in the fourth section. The article ends with conclusions and reflections.

LEARNING, DISCOURSE, DIALOGISTICS, AND POLYPHONY

A central issue of any learning theory is the fundamental question: "How do learners achieve knowledge?" The answer to this question is the starting point for designing computer tools that accompany learning processes. For example, in the seventies and eighties, the artificial intelligence research focused on developing knowledge representation techniques and programs that used knowledge stored in knowledge bases (the so-called "expert systems"), programs which were supposed to behave like humans. These goals were following the idea that knowledge can be described, stored in a knowledge base and transferred in another recipient, artificial or human. Meanwhile, learning was viewed as a process of filling the learners' minds with the knowledge from a storage base, under the assistance of artificial tutors (Intelligent Tutoring Systems). The results were not according to the great expectations, one explanation being that artificial intelligence is limited to a bureaucracy level (Winograd, 1990). We could say that what we could expect from an Intelligent Tutoring System is a professor that behaves like a bureaucrat. An alternative is to follow a hermeneutic-constructivist orientation (Winograd, 1990), which centers intelligence achievement on language pragmatics, on language interpretation and on seeing knowledge constructed in day-to-day, social life.

Computer Supported Collaborative Learning is a constructivist learning approach, based on the idea that knowledge is socially constructed (Vygotsky, 1978), and afterwards it is internalized (Stahl, 2006). Lev Vygotsky introduced the socio-cultural learning paradigm in the first half of the last century. His ideas have a permanently increasing influence on learning theories, stating that learning is a social process, mediated by specific tools, in which symbols and especially human language plays a central role (Vygotsky, 1978). However, he did not investigate in more detail how the language and discourse are actually used in collaborative knowledge building. It is the merit of Mikhail Bakhtin to propose a sound theory of how meaning is socially constructed.

Mikhail Mikhailovici Bakhtin extended Vygotsky's ideas in the direction of considering the role of language and discourse, with emphasis on speech and dialog. Bakhtin raises the idea of dialogism to a fundamental philosophical category, *dialogistics*. For example, Voloshinov (a member of Bakhtin's circle who, according to many opinions, signed a book written by his more famous friend because the former has an interdiction to publish during the Stalin regime) said: "… *Any true understanding is dialogic in nature*. Understanding is to utterance as one line of dialogue is to the next" (Voloshinov, 1973). This is in consonance with Lotman's conception of text as a "thinking device" (Wertsch, 1991), determining that: "The semantic structure of an internally persuasive discourse is not *finite*, it is *open*; in each of the new contexts that dialogize it, this discourse is able to reveal ever new *ways to mean*" (Bakhtin, 1981).

Learning may be seen as directly related to discourse building, as Sfard (2000) re-

marked: "rather than speaking about 'acquisition of knowledge,' many people prefer to view learning as *becoming a participant in a certain discourse*." Koschmann (1999) emphasized the social dimension of learning and discourse, quoting Deborah Hicks: "Learning occurs as the co-construction (or reconstruction) of social meanings from within the parameters of emergent, socially negotiated, and discursive activity" (Hicks, 1996).

Any discourse may be seen as an intertwining of at least two threads belonging to dialoguing voices. Even if we consider an essay, a novel or even a scientific paper, discourse should be considered implying not only the voice of the author. The potential listener has an, at least, as important role. The author builds a thread of ideas, a narrative. Meanwhile, in parallel to it, he/she must take into account the potential flaws of his discourse; he/she must see it as an utterance that can be argued by the listener. In this idea, discourse is similar to dialog and to music polyphony (in fact, it should not be a surprise that different art genres like music, literature and conversation have similar features), where different voices inter-animate.

Discursive voices weave sometimes in a polyphonic texture, a feature which Mikhail Bakhtin admired so much in Dostoevsky's novels. They are characterized by Bakhtin as "a plurality of independent and unmerged voices and consciousnesses" (Bakhtin, 1984).

Polyphony is not only a random overlay of voices. It has also musicality; it is in fact one of the most complex types of musical compositions, exemplified by the complex contrapuntal fugues of Johann Sebastian Bach. "When there is *more than one independent melodic line happening at the same time* in a piece of music, we say that the music is contrapuntal. The independent melodic lines are called counterpoint. The music that is made up of counterpoint can also be called polyphony, or one can say that the music is polyphonic or speak of the polyphonic texture of the music" (Polyphony, 2005).

In polyphonic music, the melodic, linear dimension is not disturbing the differential, vertical harmony. Moreover, for example, in Bach's fugues, the voices inter-animate each other: The main theme is introduced by a voice, reformulated by the others, even contradicted sometimes (e.g., inverted) but all the voices keep a vertical harmony in their diversity.

Starting from Bakhtin's ideas, we extend these ideas to collaborative learning. Therefore, we will further describe how polyphony may arise in collaborative learning and we will propose ways of supporting it in learning environments.

POLYPHONIC INTER-ANIMATION IN COLLABORATIVE LEARNING CHATS

In order to develop a theoretical background and associated supporting tools for CSCL using chats, we have analyzed the polyphonic structuring of chats in collaborative learning in two cases: mathematics problem solving and design of human-computer interfaces. The first case involved K-12 students using several instant-messaging environments. The language they used was English and, as we know, the participants were in majority native English speakers. The experiments in the second case were performed with last

year PUB students in computer science using ConcertChat (Holmer, Kienle and Wessner, 2006), chatting either in English (as non-native language) or Romanian. All the chat groups had from 3 to 5 participants. The Polyphony system, developed at PUB, was used for analyzing the polyphonic structure of all the chats.

Collaborative Solving of Mathematics Problem

The Virtual Math Teams research project investigates the innovative use of online collaborative environments to support effective K-12 mathematics learning as part of the research and development activities of the Math Forum (mathforum.org) at Drexel University. VMT extends the Math Forum's "Problem of the Week (PoW)" service by bringing together groups of 3 to 5 students in grades 6 to 11 to collaborate online in discussing and solving non-routine mathematical problems. Currently, participants interact using a computer-supported collaborative learning environment, which combines quasi-synchronous text-based communication (e.g., chat) and a shared whiteboard, among other interaction tools.

At the core of VMT research is the premise that primarily, group knowledge arises in discourse and is preserved in linguistic artifacts whose meaning is co-constructed within group processes (Schegloff, 1997). Key issues addressed by the VMT include the design challenge of structuring the online collaborative experience in a meaningful and engaging way, and the methodological challenge of finding appropriate methodological approaches to study the forms of collaboration and reasoning that take place.

Let us consider the following problem:

Three years ago, men made up two out of every three Internet users in America. Today the ratio of male to female users is about 1 to 1. In that time the number of American females using the Internet has grown by 30,000,000, while the number of males who use the Internet has grown by 100%. By how much has the total Internet-user population increased in America in the past three years? (A) 50,000,000 (B) 60,000,000 (C) 80,000,000 (D) 100,000,000 (E) 200,000,000

This problem was one of a set of eleven problems that were used for an experiment in which a group of students had to solve first individually and after that collaboratively, using chat. It was one of the two that were not solved individually by any students but it was solved collaboratively.

Let us now consider a chat excerpt that includes the main utterances that contributed to the finding of the solution (see Figure 1).

Discourse begins with Dan's idea of starting from the 30000000 number specified in the problem statement (line 357). It continues with Mic's problem solving buffoonery (lines 360-364, 366 and 368-370), remarked by Cosi (line 365) and Dan (line 367) and Mic himself (lines 364 and 366): Mic seems to start writing a reasoning but he only fakes, writing fragments of the problem statement linked by a typical phrase "… and

Line	Time	Name	Message	Interval
350	**4:31:55**	**Mic**	**how do we do this..**	
351	**4:31:59**	**Mic**	**without knowing the total number**	**0:00:04**
352	**4:32:01**	**Mic**	**of internet users?**	**0:00:02**
			. . . . .	
357	4:32:23	Dan	it all comes from the 30000000	
358	**4:32:23**	**Mic**	**did u get something for 10?**	**0:00:00**
359	4:32:26	Dan	we already know	0:00:03
360	**4:32:44**	**Mic**	**30000000 is the number of increase in american females**	**0:00:18**
361	**4:33:00**	**Mic**	**and since the ratio of male to female**	**0:00:16**
362	**4:33:02**	**Mic**	**is 1 to 1**	**0:00:02**
363	**4:33:09**	**Mic**	**that's all i got to give. Someone finish it**	**0:00:07**
364	**4:33:10**	**Mic**	**Haha**	**0:00:01**
365	*4:33:18*	*Cosi*	*Haha you jackass*	*0:00:08*
366	**4:33:20**	**Mic**	**Haha**	**0:00:02**
367	4:33:21	Dan	Hahaha	0:00:01
368	**4:33:26**	**Mic**	**u all thought i was gonna figure it out didn't**	**0:00:05**
369	**4:33:27**	**Mic**	**U**	**0:00:01**
370	**4:33:28**	**Mic**	**huh?**	**0:00:01**
371	4:33:28	Hal	it would be 60,000,000	0:00:00
372	**4:33:30**	**Mic**	**Hal**	**0:00:02**
373	**4:33:31**	**Mic**	**its all u**	**0:00:01**
374	**4:33:33**	**Mic**	**See**	**0:00:02**
375	**4:33:34**	**Mic**	**i helped**	**0:00:01**
376	*4:33:54*	*Cosi*	*ok, so what's 11 – just guess on 10*	*0:00:20*
			. . . . .	
386	**4:34:45**	**Mic**	**lets get back to 5**	
387	*4:34:47*	*Cosi*	*i think it's more than 60,00000*	*0:00:02*
388	**4:34:57**	**Mic**	**way to complicate things**	**0:00:10**
389	*4:35:03*	*Cosi*	*Haha sorry*	*0:00:06*
390	**4:35:05**	**Mic**	**life was good until you said that**	**0:00:02**
391	**4:35:07**	**Mic**	**:(**	**0:00:02**
392	*4:35:18*	*Cosi*	*they cant get higher equally and even out to a 1 to 1 ratio*	*0:00:11*
393	*4:35:27*	*Cosi*	*oh, no wait, less than that*	*0:00:09*
394	*4:35:32*	*Cosi*	*50000000*	*0:00:05*
395	*4:35:34*	*Cosi*	*yeah, it's that*	*0:00:02*
396	*4:35:36*	*Cosi*	*im pretty sure*	*0:00:02*
397	**4:35:37**	**Mic**	**Haha**	**0:00:01**
398	**4:35:38**	**Mic**	**how?**	**0:00:01**
399	*4:35:57*	*Cosi*	*because the women pop had to grow more than the men in order to even out*	*0:00:19*
400	*4:36:07*	*Cosi*	*so the men cant be equal (30)*	*0:00:10*
401	**4:36:11**	**Mic**	**oh wow...**	**0:00:04**
402	**4:36:16**	**Mic**	**i totally skipped the first sentencwe**	**0:00:05**
403	*4:36:16*	*Cosi*	*Therefore, the 50,000,000 is the only workable answer*	*0:00:00*
404	4:36:19	Dan	very smart	0:00:03
405	*4:36:21*	*Cosi*	*Damn im good*	*0:00:02*

Figure 1. An excerpt illustrating a collaborative solution construction

since … ." However, this fake discourse fragment seems to belong to a mathematics speech genre and, even being a pastiche, is continued by Hal which extrapolates the 1:1 ratio from the present (as stated in the problem) to the whole 3 years and advances 60000000 as a solution (line 371).

Mic continues the buffoonery (lines 372-375), claiming that he helped Hal to find the

supposed (wrong) solution. After a while, Cosi's (incorrect) utterance "i think it's more than 60,00000" appears as a critique, as an intuition of something wrong, of some kind of an "unsuccessful story," or some "dissonant" chord. Nevertheless, after less than another minute, she realizes that her own supposition is wrong because the ratio cannot be 1:1 or bigger.

The collaborative discourse enabled Cosi to solve the problem. She did not solve it in the first phase, when they had to solve it individually. However, when she listened to the discourse proposing a solution (correct in the case of Dan's beginning proposal, fake at Mic and wrong at Hal), she felt the need to put herself on a different position. Therefore, the discourse acted as a tool, as an artifact that enabled Cosi to find the correct answer.

Polyphonic Structuring in Chat Conversations

Discourse in collaborative chats has an obvious sequential, longitudinal, time-driven structure in which the listeners are permanently situated and in which they emit their utterances in a threaded manner. In parallel with this linear threading dimension, in problem solving chats, the participants situate themselves meanwhile also on a critical, transversal (or differential) position. For example, in the chat excerpt considered in the preceding section, Dan's theme was continued by Mic's buffoonery, continued itself by Hal and then contradicted by a first theme of Cosi that was eventually totally changed, in its opposite.

In this longitudinal-transversal space, voices behave in a unity-difference manner (or centripetal-centrifugal, Bakhtin, 1981). This phenomenon is not specific solely to chats. It appears also to polyphonic music: "The deconstructivist attack (…) – according to which only the difference between difference and unity *as an emphatic difference* (and not as a return to unity) can act as the basis of a differential theory (which dialectic merely claims to be) – is the methodical point of departure for the distinction between polyphony and non-polyphony." (Mahnkopf, 2002).

Interactions of voices towards the unity and difference dimensions were identified in all chats we have analyzed. Some of these interactions may be abstracted in classes of *inter-animation patterns* in which an utterance of a voice is the cause of the utterance of another voice. In the next section, patterns of inter-animation are identified along the unity-difference dimensions. The subsequent section will discuss how these interactions weave into a polyphonic structure.

Inter-Animation Patterns

When somebody listens to Johann Sebastian Bach's fugues or even other classical music works, he remarks how several themes and their variations are exposed, developed and re-exposed by several instruments. Moreover, these themes and their variations seem to inter-animate (even the name of musical "fugue" expresses exactly the idea that several voices are "running" and "chasing" one each other).

Bakhtin used the musical metaphor for linguistics, considering that "the voices of others become woven into what we say, write, and think" (Koshmann, 1999). Therefore, for analyzing CSCL chats, it is needed to investigate how voices are woven in discourse, how themes and voices inter-animate in a polyphonic way. This is important not only to understanding how meaning is created but also for trying to design tools for support and evaluation.

Specific inter-animation patterns may be identified along each of the unity and difference dimensions in a chat. In CSCL, each of these patterns may be used for automatic abstraction of useful data, either for the participants in a chat, or for teachers, towards evaluation purposes. Such an application, using natural language processing, is presented in the end of this article.

Unity inter-animation patterns are characterized by their trend towards continuity and achieving coherence in the chat. A first such class of patterns is *adjacency pairs* (Sacks et al., 1974), containing couples of logically succeeding utterances like question-answer, for example, utterances 398 and 399 in Figure 1, or utterances 68-69, 71-72, 73-74, 76-77 in the following example:

68 mathisfun: see angle alpha?
69 bob123: yes
70 bob123: what about it?
71 mathisfun: is that 60 degrees?
72 bob123: yes
73 mathisfun: can u use the degree, 2 length to find the last length of a triangle?
74 bob123: i don't get what you're saying
75 mathisfun: the two arrow pointed lengths and the angle can find the length A
76 bob123: by what?
77 mathisfun: the two sides and the degree

Other adjacency pairs may be identified, for example, greeting-greeting (19-20, 21-22):

19 john: hi all
20 dan: hi john
21 mary: happy birthday, john!
22 john: thanks mary!

The first utterance in an adjacency pair normally requires (in a coherent dialog) the emitting of the second utterance.

Question-answer adjacency pairs are important in learning because they force the students to participate, to face questions, to answer and, implicitly, to reason and understand the discussed problems. Other adjacency pairs have been identified in CSCL. For example, Stahl has identified *math proposal adjacency pairs*, with the structure:

1. An individual makes a proposal to the group for the group's work.
2. Another member of the group accepts or rejects the proposal. (Stahl, 2006)

A second unity inter-animation pattern is *repetition*, which plays an important role in creating coherence in a discourse. Repetition may appear along a much larger number of utterances than an adjacency pair. Tannen (1989) considers that repetitions may be seen as a kind of rhythm making with a main role in enhancing the involvement of the participants in a dialogue. The following excerpt (which is a transcript of a face-to-face conversation in the Jeffersonian notation) exemplifies these ideas:

1:21:53 Teacher: And you don't have anything like that there?
1:21:56 Steven: I don't think so
1:21:57 Jamie: Not with the same engine
1:21:58 Steven: [No
Jamie: [Not with the same
1:21:59 Teacher: With the same engine … but with a different (0.1) … nose cone?=
1:22:01 Chuck: [=the same=
Jamie: [=Yeah,
1:22:02 Chuck: These are both (0.8) the same thing
1:22:04 Teacher: Aw [right
1:22:05 Brent: [This one's different
(Stahl, 2006)

Socialization or jokes are also a way of unity making. For example, many times participants in chats feel the need to joke, probably for establishing a closer relation with the other participants, in order to establish maybe a group flow state (Csikszentmihalyi, 1990). In fact, in all the chats we examined there is a preliminary socialization phase.

Another interaction pattern is *cumulative talk* (Mercer, 2000) or, in Sacks' words, *collaborative utterances* (Sacks, 1992). In such a situation, several participants jointly utter a sentence, like a single person:

Joe : (cough) We were in an automobile discussion,
Henry : discussing the psychological motives for
Mel : drag racing on the streets
(Sacks 1992, pp.144-5)

A second example of cumulative talk is the inter-animation of mathpudding and mathman, in a VMT mathematic problem solving chat:

117 ModeratorSf: could you guys tell templar what's going on?
118 mathpudding: we're experimenting with circles
119 mathman: and finding as many possible relations as we can

The last unity inter-animation pattern we will discuss here is *convergence*, which is an utterance that links two discussion threads having different topics. For example, in Figure 2, utterance 34 links the discussion thread on "(re)presentation" with the one on "topic." Convergence is an extremely important pattern, being considered by Roschelle (1992) the crux of collaboration.

Difference inter-animation patterns are inherent to chat conversations. Disputes or negotiations are inter-animated by differences and opposite positions. Difference making has a crucial role in chats for collaborative learning, a role that may best be understood from a polyphonic, musical perspective. The possibility of contemplating (listening) from a critical position the ideas (melodies) of other people and entering into negotiation and argumentation (polyphony of voices) enhances problem solving and enables learning through a trial-error process. Such processes appear also in individual learning (we can say that thinking is also including multiple inner voices), but the presence of multiple participants enhances both the possibility of developing multiple threads and, meanwhile, of differences identification. The inter-animation of the multiple perspectives of the participants, the opposition as a result of contemplation and the presence of a third opinion in case of conflict, and sometimes the synthesis it brings are a better asset to success than a multi-voiced discourse performed by an individual (as inner thinking), that is inherently much less critique.

Several classes of difference inter-animation patterns may be identified. There are simple, obvious differential utterances that disapprove an assertion:

371	4:33:28	Hal	it would be 60,000,000
387	4:34:47	Cosi	i think it's more than 60,00000

There is difference making that not only disapproves an assertion but also proposes a development:

392	4:35:18	Cosi	they cant get higher equally and even out to a 1 to 1 ratio

Sometimes, the participants even explicitly state that they found a difference:

p4nzer: agree with me so far?
tricavl: yes, but i did the same thing
tricavl: the difference was the place of the space :).
petry_g: and the number of moves :)

The chat excerpt used above for the exemplification of repetitions ends with an extremely important difference making, which, in fact, is the moment of finding the solution (Stahl, 2006). In fact, we could say that learning is achieved in many situations by understanding significant differences.

Evidence that participants permanently keep a differential position is also provided

by the statistics of personal pronoun usage in chat sessions. For example, in a corpus of chats recorded in May 2005, "I" was used 727 times, much more than the usage of "we," with 472 occurrences. First person "me" was used 84 times comparing to "us," used only 34 times. However, the second person addressing is very well represented by 947 uses of "you."

Polyphonic Multi-Threaded Inter-Animation

In the CSCL experiments described in this article there is either a problem to be solved or an interface to be designed. In almost all of these chats, the interactions are structured in a polyphonic manner. All these chats, similarly to a musical piece, have as a main theme (or topic) the problem to be solved or to be designed. This theme generates threads of discussions that may be seen as variations (sub-topics) of the theme, in the same way as musical variations. If these threads do not respect harmony constraints, differential inter-animation patterns apply and the effect is that participants emit a correcting utterance.

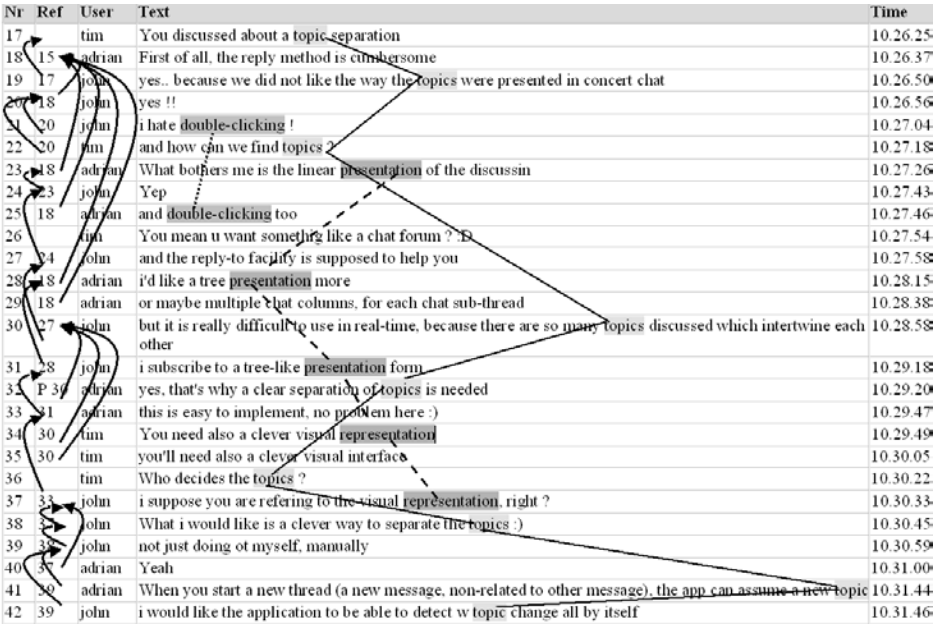
For illustrating the weaving of several threads in a polyphonic way in sequential and differential dimensions that inter-animate, we will consider a chat from a series of experiments performed with computer science students in the final year at the "Politehnica" University of Bucharest, for a Human-Computer Interaction course. In this chat, from which an excerpt is shown in Figure 2, students had to discuss about what facilities and tools should have a collaborative environment.

The chat system used in the chat session was ConcertChat (http://www.ipsi.fraunhofer.de/concert/index_en.shtml?projects/chat), which allows the users to explicitly reference the utterance to whom they reply (Holmer, Kienle and Wessner, 2006). The students were encouraged to use the referencing facility as much as they consider.

Each of the participants may be considered as a distinct voice (in Bakhtin's sense), which utters new subjects by introducing new themes in the discourse, or iterates an already uttered theme, using his/her own "voice." For example, in Figure 2, three themes are emphasized: "double-clicking," the "topics" in a collaborative chat, and ways of "presentation." The repetition inter-animation pattern is obvious, the last two themes being considered repeatedly by all the three students. The repetitions may be used for detecting (by the Polyphony system, described in the next section) implicit links, shown by straight lines in Figure 2.

As may be seen, in Figure 2 there are two types of threads. A first type includes the above-mentioned, implicit chains of semantically related arguments, centered on repeated words (a case of repetition inter-animation pattern), which may be seen as themes. The second type of threading (represented by curly arrows in the left part of Figure 2) is explicitly marked by the chat participants using ConcerChat's referencing facility. What is interesting is that this second type of link is many times not corresponding to the first one.

In Figure 3 is represented the participation of the three voices (students) in the development of the above three threads. Time flows from left to right and the same repre-



Nr	Ref	User	Text	Time
17		tim	You discussed about a topic separation	10.26.25
18	15	adrian	First of all, the reply method is cumbersome	10.26.37
19	17	john	yes.. because we did not like the way the topics were presented in concert chat	10.26.50
20	18	john	yes !!	10.26.56
21	20	john	i hate double-clicking !	10.27.04
22	20	tim	and how can we find topics ?	10.27.18
23	18	adrian	What bothers me is the linear presentation of the discussin	10.27.26
24	23	john	Yep	10.27.43
25	18	adrian	and double-clicking too	10.27.46
26		tim	You mean u want something like a chat forum ? :D	10.27.54
27	24	john	and the reply-to facility is supposed to help you	10.27.58
28	18	adrian	i'd like a tree presentation more	10.28.15
29	18	adrian	or maybe multiple chat columns, for each chat sub-thread	10.28.38
30	27	john	but it is really difficult to use in real-time, because there are so many topics discussed which intertwine each other	10.28.58
31	28	john	i subscribe to a tree-like presentation form	10.29.18
32	P 30	adrian	yes, that's why a clear separation of topics is needed	10.29.20
33	31	adrian	this is easy to implement, no problem here :)	10.29.47
34	30	tim	You need also a clever visual representation	10.29.49
35	30	tim	you'll need also a clever visual interface	10.30.05
36		tim	Who decides the topics ?	10.30.22
37	33	john	i suppose you are refering to the visual representation, right ?	10.30.33
38	35	john	What i would like is a clever way to separate the topics :)	10.30.45
39	35	john	not just doing ot myself, manually	10.30.59
40	37	adrian	Yeah	10.31.00
41	39	adrian	When you start a new thread (a new message, non-related to other message), the app can assume a new topic	10.31.44
42	39	john	i would like the application to be able to detect w topic change all by itself	10.31.46

Figure 2. Two types of threads in the chat

sentation of the themes (shadowing and types of lines) is kept. In addition to the sequential dimension of theme development, in the same figure are represented also (by thick arrows) two interactions between themes, which may be considered as a transversal interaction pattern between themes; the first is a unity convergence inter-animation and the second might be seen as a difference pattern. Such a situation is similar to the contrapuntus used in classical music, where several voices inter-animate.

According to Bakhtin's perspective, we may consider that the themes, during their development, are filled with the overtones of the voices of the contributors. In addition to their sequential intertwining, voices interact transversally, they inter-animate, the themes weaving like in a musical polyphony.

SUPPORT FOR POLYPHONIC INTER-ANIMATION IN CHATS

Even if there are different views on what CSCL is and what the role of computers is in CSCL (communication media, simulation tool, etc.), a constant feature is the usage of natural language dialogue. Computer and communication technologies offer natural language interaction tools, like instant messaging (chats) or forums of discussions, which support collaboration. However, they were not developed for learning purposes and it is important to develop additional facilities for enhancing CSCL.

Support tools for CSCL chats should, in our opinion, encourage polyphonic inter-animation, in several ways. First of all, the generation of multiple discussion threads

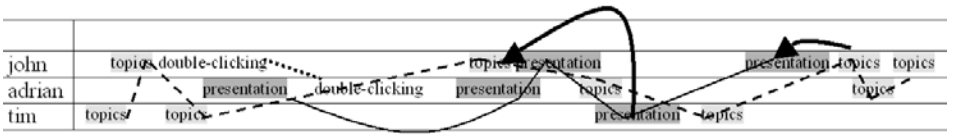


Figure 3. Polyphonic inter-animation of the threads from figure 2

should be encouraged. This idea is proposed, in another form, also by the referencing facility in ConcertChat.

Secondly, similarly to music composition, the creation of variations on each thread is a source of polyphony development. These variations on multiple threads should be the subject of difference inter-animation patterns. Eventually, the possibility of "listening" to the polyphonic construction is extremely important for several reasons, like the creation of new variations and for difference inter-animation. However, instead of "listening" to the "sounds," we rather propose the usage of a graphical presentation of the polyphonic structure of the conversation, somehow similar to a musical score.

The only additional computer support in the examples of chats from previous sections was the referencing facility of ConcertChat, which encourages the co-existence of multiple discussion threads. In collaboration using any instant messenger tools it is possible to achieve, in much more degree than in the face-to-face case, a multiple threaded discourse, including several sequences of utterances in the same time. It is true that also in face-to-face conversations more than one discussion thread may appear, but, due to the fact that it is hard to follow a conversation where more than one voice is speaking at a time, this situation is not common. However, the multiple threading in ordinary chat systems, if it is not supported by additional facilities, may drive to confusion (for example, if an approval utterance follows two utterances of different persons that ask something, it may be unclear to whom it is addressed). Fortunately chat systems like ConcertChat allow the users to explicitly reference the utterance to which they reply (Holmer, Kienle and Wessner, 2006). For example, in Figure 2, several discussion threads co-occur, as shown by the curly arrows in the left.

The second and third requirements, previously discussed in this section, may be fulfilled if software tools are developed for the detection and the visualization of inter-animation patterns and threads. Such a groupware, named "Polyphony," has been developed at PUB. The system is built around a chat system, and has some modules not present in usual instant messaging. These modules offer abstractions of the ongoing chat, in the idea of making clear the flow of ideas and the inter-animation of the "voices" (the melody) and, the most important, to induce polyphonic, differential ideas. There are modules that may summarize a conversation or that can evaluate the contributions of each participant to the conversation.

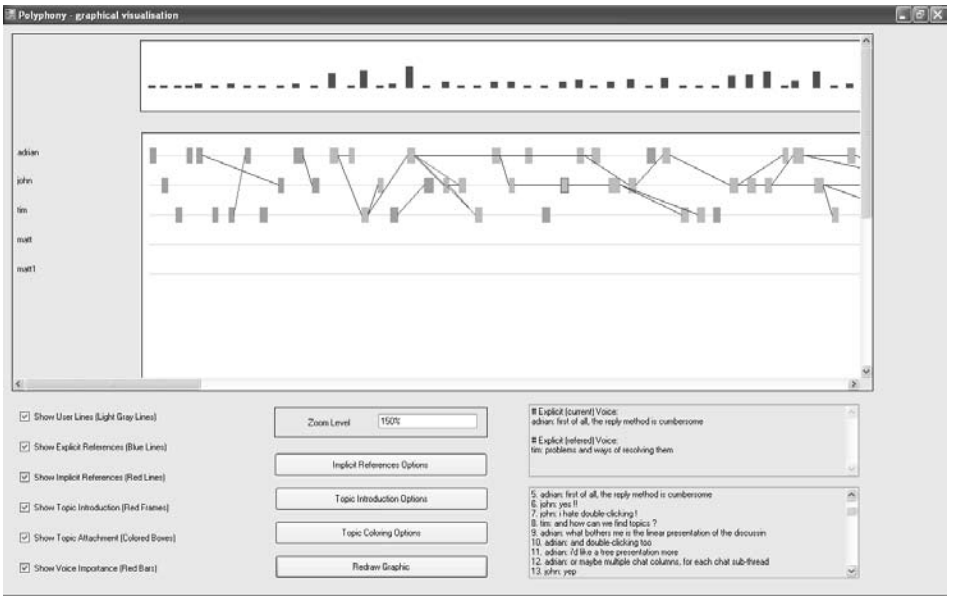


Figure 4. Graphic visualization of a chat and of the influence of the voices of the participants

Figure 4 is a snapshot of the tool developed in Polyphony for the graphical representation of the chats and of the influence of the participant voices, starting from the polyphony theory of Bakhtin (Trausan-Matu et al., 2007). For each participant in the chat, there is a separate horizontal line in the representation and each utterance is placed in the line corresponding to the issuer of that utterance, taking into account its positioning in the original chat file – using the timeline as an horizontal axis. Each utterance is represented as a rectangle aligned according to the issuer on the vertical axis and having a horizontal axis length that is proportional with the dimension of the utterance. The distance between two different utterances is proportional with the time passed between them.

The relationships between utterances are represented using colored lines that connect these utterances. The explicit references, that are known due to the use of the ConcertChat software, are depicted using blue connecting lines, while the implicit references that are deduced using natural language processing (Trausan-Matu et al., 2007) are represented using red lines. These implicit links represent inter-animation patterns (adjacency pairs, repetitions, difference patterns, etc.) that were automatically detected.

At the top of the graphical representation of the conversation there is a special area that represents the importance of each utterance as a rectangle, considered as a chat voice, in the conversation. This importance is computed using some heuristics that consider the effects of the utterances on the rest of the conversation (Trausan-Matu et al., 2007). For example, in Figure 4, the highest rectangle corresponds to the utterance number 18 in Figure 2, which has been explicitly linked to many other utterances.

CONCLUSIONS

The goal of CSCL chats is to make students jointly construct meaning (for example, mathematical problem solving or designing an artifact), starting from a given theme (problem). In a chat conference, in the process of a theme's development, there may be several parallel discussions threads. The simplest case is similar to the face-to-face situations, when there is one discussion thread at a time. A more complex case is that in which two or more independent discussion threads are going in parallel, a situation possible when using chat conferences.

Obviously, a CSCL chat in which there are a number of totally independent discussion threads is not desired. This would be equivalent to the existence of that number of different conversations. The idea of collaboration is to involve all the participants together, while allowing several threads of discussion. Therefore, it is very important to involve them as a group, to make them inter-animate. For exploring the ways people use inter-animation techniques in conversations, a very good model is music polyphony, idea introduced by Mikhail Bakhtin (1981, 1984).

Discourse in chats implies the inter-animation of multiple voices along two dimensions, the sequential, utterance threading and the transversal, differential one. These two dimensions correspond to a unity-difference (or centrifugal-centripetal, Bakhtin, 1981) basic feature of polyphony. For each dimension, specific patterns were identified and discussed. These inter-animation patterns were identified in many chats, both at English native speakers (in the VMT project) and at Romanian students speaking English.

The unity directed dimension is achieved at diverse discourse levels by adjacency pairs, repetitions, collaborative utterances, and convergence patterns. The second, differential dimension, could be better understood if we consider discourse as an artifact that, taking into account that every participant in collaborative activities has a distinct personality, is a source of a critical, differential attitude. Even if individual, the inner discourse may be multi-voiced; however, difference and critique are empowered in collaborative contexts, in a community of different personalities.

A consequence of the sequential-differential perspective for the design of CSCL environments is that they must facilitate inter-animation not only on the longitudinal dimension, through threading but also the transversal, differential, critical dimension. Tools that may enter in this category should be able to provide visualizations, abstractions or summarizations of previous discourse, in order to facilitate differential position taking. They should also allow the participants to emphasize the different proposed themes and to relate them in threads, polyphonically.

The article proposes also a tool that graphically visualizes the threads in a chat and the influence that an utterance has on the subsequent ones. This tool offers abstraction means, which may be used the identification of chats that have a high degree of inter-

animation (chats whose representation has a graph with many edges) and, in a given chat, for the identification of the segments where several threads are going in parallel. This data is extremely useful, for example, for a professor who examines in what degree students have interacted in a chat, what were the topics, how they weaved and who had the most influential ideas. For students, the system may be used for self-assessment.

Some critical reflections about the developed tools should remark that the detection of implicit links (not explicitly referred by the ConcertChat facility) in threads is difficult, due to the limitations of the natural language processing techniques and to the ambiguity of the natural language. Another issue that needs further research and implementation is the automatic detection of transversal, differential inter-animation patterns. In the current version, only simple adjacency pairs, like question-answer or agreement-disagreement, and repetitions are detected.

Wegerif also advocates the use of a dialogic framework for teaching thinking skills by inter-animation: "meaning-making requires the inter-animation of more than one perspective" (Wegerif, 2005). He says that questions like "'what do you think?' and 'why do you think that?' in the right place can have a profound effect on learning" (Wegerif, 2005). He is proposing, from our perspective, the inducing of adjacency pairs to inter-animate the discourse. However, he did not remark the polyphonic feature of inter-animation.

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