

Analysing Learner Interaction in an Adaptive Communication Tool

Agoritsa GOGOULOU, Evangelia GOULI and Maria GRIGORIADOU
*Department of Informatics & Telecommunications, University of Athens,
Panepistimiopolis, Ilissia, Athens 15784, Greece*
rgog@di.uoa.gr, lilag@di.uoa.gr, gregor@di.uoa.gr

Abstract. This paper presents an approach to analyse learner interaction, both quantitatively and qualitatively, in the context of a synchronous adaptive communication tool, named ACT. The quantitative analysis aims to provide information about learners' contributions to the dialogue and the results are presented in a graphical form. The qualitative analysis aims to exploit various attributes regarding learners' contributions and investigate their collaboration behavior in terms of collaboration indicators. The analysis focuses on (i) the cognitive skills that learner develops with respect to the learning outcomes addressed by the activity, and (ii) the behavior that learner exhibits in promoting the collaboration by initiating/stimulating and advancing the discussion. The teacher has the possibility to personalize the analysis process by defining weights to the attributes analysed denoting this way their importance with respect to the underlying activity. Indicative cases from the formative evaluation of the ACT tool illustrate and explain the proposed collaboration indicators.

Introduction

Towards the direction of supporting learners during their collaboration, research efforts attempt to either structure the collaboration or regulate the collaboration or both [3]. In this context, the automatic analysis of learners' interaction is at the forefront of research in the field of Computer Supported Collaborative Learning (CSCL) and concerns learners' dialogue if synchronous or asynchronous text-based communication is supported and/or learners' actions if shared group workspaces are available. The analysis process includes (i) data selection regarding learners' contributions (messages and/or actions) and (ii) application of processing methods in order to aggregate the selected data and produce one or more *indicators* that indicate the 'quality' of the individual activity, the 'quality' of the collaboration, and/or the quality of the collaborative product [8].

Barros & Verdejo in their asynchronous newsgroup-style system called DEGREE [2], use the structured form of the dialogue in terms of asking learners to denote their contribution type from a predefined set, with respect to the underlying conversational structure. The system records all the actions performed by the learner and supports both a quantitative and a qualitative analysis resulting in to output ratings for attributes such as attitude and promote discussion. The ratings are exploited by an advisor agent offering tips on improving learners' interaction. Synergo [1] builds on the Object-oriented Collaboration Analysis Framework (OCAF) where learner interaction and workspace actions are analysed from the shared objects' point of view. The objects that learners manipulate independently compile statistics on their use, and contribute to the definition of indicators describing their owners' collaboration behavior. The collaboration factor (CF) is proposed, which provides a degree of collaboration of the group and is graphically displayed on the time axis, facilitating the analysis of collaboration over a set time period. Padilha et al [9] propose performance reports based on a set of quantitative (e.g. interaction numbers in chat tool) and qualitative (e.g. degree of explanations sent) indicators. In the EPSILON system [10],

learners collaboratively solve object-oriented design problems while they communicate through sentence openers. The system codes learners' communication and actions and determines whether or not they effectively share new knowledge and what sort of guidance might be helpful by applying the Hidden Markov Model technique.

Our research efforts extend previous work in interaction analysis in synchronous text-based communication tools. More specifically, we attempt (i) to analyse learners' interaction (i.e. dialogue) with respect to the learning outcomes addressed by the collaborative activity or the model of collaboration followed, and (ii) to offer teachers the possibility to personalize the analysis process by defining weights to the attributes analysed denoting this way their importance with respect to the underlying activity. To this end, in the context of the ACT (Adaptive Communication Tool) tool, we follow a quantitative and a qualitative approach aiming to analyse and investigate learner collaboration behavior in terms of Learner Indicators and group collaboration behavior in terms of Group Indicators. The work presented in this paper focuses on Learner Indicators.

The rest of the paper is structured as follows. In Section 1, a brief overview of the ACT tool is given while in Section 2 we present the modeling of the scaffolding sentence templates on which the dialogue is based. Section 3 is devoted to the description of learner indicators illustrating and explaining them through specific case studies. The paper ends with the main points of our work and our near future plans.

1. The ACT Tool

ACT (Adaptive Communication Tool) supports the synchronous communication of learners in groups of up to four persons in the context of a collaborative activity. The activity may address cognitive skills that are classified to one of the four levels: *Comprehension level* (Remember + Understand), *Application level* (Apply), *Checking-Critiquing level* (Evaluate) and *Creation level* (Analyse + Create) [4]. Moreover, a specific model of collaboration is followed; the group members may collaborate either having the same duties or undertaking different roles. In any case, one of the group members plays the role of the moderator, being responsible for the coordination of the group process (e.g. proceed to the next question), the summarization of the debate and the submission of the answer.

The automatic analysis of the dialogue is quite difficult, in cases where the free dialogue is supported. In order to facilitate the tracing of the dialogue states and enable the automatic interpretation of learners' interaction [6], the structuring of the dialogue through sentence openers or communication acts is usually supported. Towards this direction, the ACT tool follows the structured form of the dialogue, aiming to (i) guide learners towards the underlying learning outcomes of the activity or the duties and responsibilities implied by the model of collaboration, and (ii) enable the automatic analysis and interpretation of learners' interaction. In ACT, the structured form of the dialogue is supported utilizing both sentence openers and communication acts. The provided *Scaffolding Sentence Templates* (SST) (i.e. sentence openers and communication acts) are adapted on the basis of (i) the level of the learning outcomes (i.e. cognitive skills) addressed by the activity, and (ii) the specific roles that learners undertake in the context of a specific model of collaboration [4]. More specifically, the sentence openers are aligned with the Comprehension, Application and Checking-Critiquing level of the cognitive skills, while the communication acts are aligned with the Creation level and the role that each learner undertakes. Also, the communication acts are used in case learning activities do not explicitly address one out of the four above mentioned levels of cognitive skills, but they rather aim to enable learners to discuss/exchange ideas on a specific topic or on the subject/solution of the activity.

All the group members have at their disposal the same set of SST if they collaborate having the same duties; the moderator of the group has available additional SST compatible to the additional duties. In case a model of collaboration with roles is followed, the provided SST are different for the group members supporting their roles appropriately [4]. Besides the predetermined sets of SST, a learner may determine his/her own SST in case the available ones do not cover his/her needs. The learner's determined SST are part of his/her learner model and are available each time s/he uses the ACT tool.

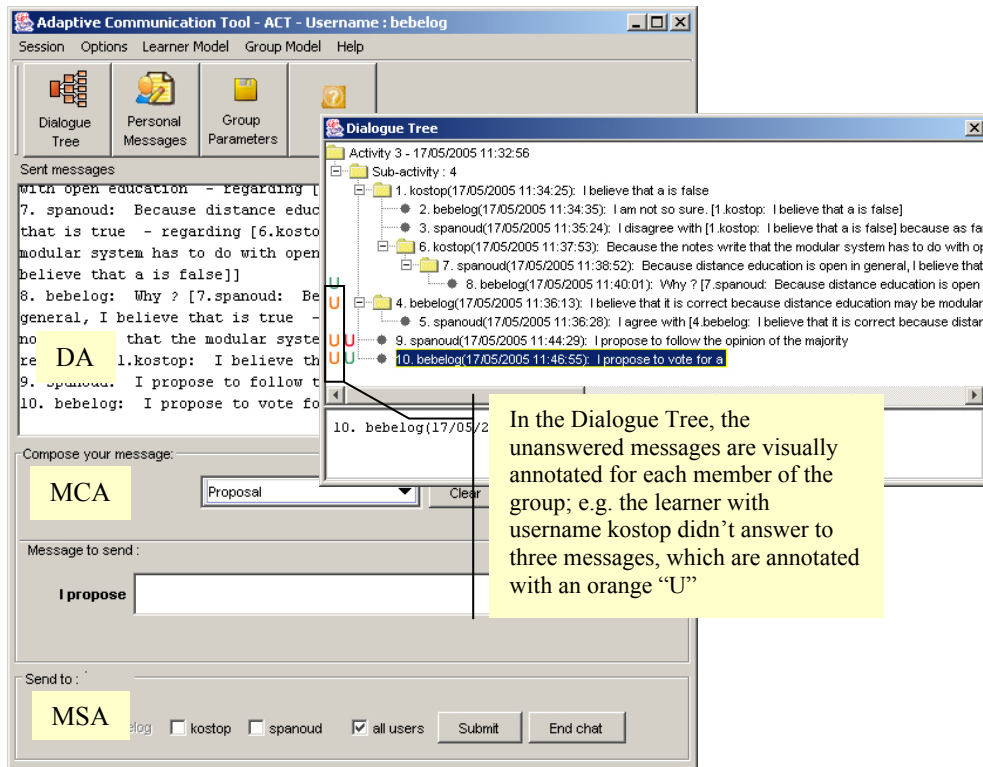


Figure 1. A screenshot of the ACT tool with the “Dialogue Tree” window. The Dialogue Area (DA) presents the messages in a chronological sent order; the Message Composition Area (MCA) enables learners to select the desired SST and compose their message; the Message Submission Area (MSA) enables learners to submit their message to all or to selected members of the group.

During the collaboration, learners can have access to their model as well as to the group model in order to have an insight to their own contributions and to their collocutors' contributions in a graphical form. Figures 2 and 3 present the contributions of two groups respectively; the left (blue) column corresponds to the group's contributions followed by a coloured column for each member of the group. This facility acts as a mirroring tool and supports the regulation process. The messages are grouped according to the message they are referring to and are visually represented in a tree structure through the “Dialogue Tree” window. In particular, ACT supports a facility for the automatic construction and update of the Dialogue Tree as learners submit their messages. The learners have access to the Dialogue Tree at any time during the communication. Such a graphical representation of the dialogue enables learners to trace the sequence of the dialogue more easily, to have a clear view of the dialogue progress and to receive feedback, in a visual form, about their contributions (e.g. in the Dialogue Tree presented in Figure 1, following the analysis of the dialogue, the unanswered messages are notified for each member of the group with a different colour in correspondence to the colours used in the graphical representation of their contributions). Therefore, the Dialogue Tree can stimulate learners to reflect on their dialogue and improve their participation.

2. Modeling Scaffolding Sentence Templates

The predetermined SST as well as learner's defined SST are categorized to one or more of the following *discourse categories*: Proposal (P), Opinion (O), Question (Q), Reasoning (R), Clarification (C), Agreement (A), Disagreement (D), Inference (I), Motivation (M), Need (N) and Social Comments (S). The predetermined set of the SST includes:

- (i) a subset dedicated to the development/cultivation of cognitive skills aligned with the addressed learning outcomes,
- (ii) a subset facilitating the communication, and
- (iii) a subset available only to the moderator of the group.

Each SST is defined as a set of the following attributes:

- *SSTT* (SST Type): the type of the SST may be either a Sentence Opener or a Communication Act.
- *ST* (Skill Type): the type of the skills that the SST mainly concerns, may be either cognitive, with respect to the activity under consideration, or communication.
- *OL* (Outcome Level): the outcome level that the SST is aligned with.
- *DC* (Discourse Category): the discourse category of the SST denoting the intention of learner's contribution.
- *SR* (Supporting Roles): the roles that the SST serves in case the model of collaboration implies specific roles to the group members with specific duties and responsibilities.
- *T* (Text): the text forming the SST, which may be composed of one or two parts depending on the number of arguments.
- *FA* (Filling Actor): if the SST consists of one or more arguments, then the argument(s) may be filled either by the learner (in case of text field) or the tool (in case of a reference to an already sent message) or both.
- *UI* (User Input): in case that the argument of the SST is a text field, the user input may be optional or obligatory.
- *W* (Weight): the degree of the SST denoting the value of the underlying contribution ($w \in [0, 100]$).

To clarify the above attributes, let's consider the following examples of SST:

{SO, CS, C, P, null, "I propose", U, Ob, 100}: The Sentence Opener "I propose" concerns Cognitive Skills, is aligned with the Comprehension level of learning outcomes, denotes learner's intention to contribute to the dialogue through a Proposal, the accompanying text field has to be filled in by the User and is considered Obligatory, and the weight of the SST is 100.

{CA, CS, null, A, Assessor-Driver, "Agreement", SU, Op, 80}: The Communication Act "Agreement" concerns Cognitive Skills, denotes learner's intention to make an Agreement, is made available to those learners undertaking the role of Assessor in the context of the "Brainstormer-Assessor" collaboration model or the role of Driver in the context of the "Driver-Observer" collaboration model, the accompanying arguments include (i) a reference to an already sent message; the already sent messages are made available by the System, and (ii) a text field, which has to be filled in by the User and is considered Optional, and the weight of the SST is 80.

In case of learner's defined SST, the values of ST and W are inferred from the learner's defined DC and the correspondence between the DC, ST and W values as assigned by the teacher. The weights assigned by the teacher reflect the degree of importance of the provided SST with respect to the learning outcomes addressed by the activity. This way, the teacher has the possibility to personalize the analysis process of learners' interaction. For example, in case the teacher wishes to analyse and have an evidence of learners' ability to make proposals and provide explanations or arguments, s/he may set higher weights to SST belonging to the discourse categories of Proposal and Reasoning.

3. Collaboration Indicators

The analysis of learners' interaction follows both a quantitative and a qualitative approach. The quantitative analysis aims to provide information about learners' contributions to the dialogue and the results are presented in a graphical form, as described in Section 1, while the qualitative analysis aims to exploit various characteristics regarding learners' contributions and investigate (i) learner collaboration behavior in terms of Learner Indicators and (ii) group collaboration behavior in terms of Group Indicators. The design of the analysis process and subsequently of the supported indicators is based on the design principles of the ACT tool as well as on the literature research [5], [7], regarding the skills that contribute to a creative and "good" collaboration. In the context of the current work, we describe the Learner Indicators and elaborate on them through specific empirical data.

3.1 Learner Indicators

As one of the main objectives of the ACT tool is to guide learners towards the development of cognitive skills in line to the addressed learning outcomes, it is considered necessary to analyse learners' contribution in view of this perspective. As stated above, the teacher has the possibility to assign the desired weights to the provided SST taking into account the learning outcomes and the discourse category of the SST. In this sense, the *Cognitive Skills Indicator for the i th Learner ($CSI(L_i)$)* is defined as the sum of the weights of the SST used by the learner during the communication (Formula F1). Depending on the weights assigned to the SST, this indicator denotes the degree that the learner contributes to the dialogue using SST aligned with the cognitive skills addressed by the learning activity; and subsequently, the degree of cultivating such skills.

$$CSI(L_i) = \sum_{\text{for all SST used by } L_i} W_{SST} \quad (F1)$$

During the collaboration, the learner may exhibit initiatives in promoting the dialogue/collaboration by (i) making proposals or expressing an opinion and in this way initiating/stimulating the discussion, (ii) answering to the contributions of other group members (whether it is required or not) or elaborating further on his/her own contributions by reasoning for his/her point of view, and (iii) elaborating on a point of view although it is not considered necessary. More specifically:

- The *Initiating the Discussion Indicator for the i th Learner ($IDI(L_i)$)* concerns the first abovementioned point and it is measured as the sum of all the messages sent, characterized as proposals or opinions in the total of all the sent messages; Formula (F2) quantifies the degree of learner's initiative to stimulate the discussion:

$$IDI(L_i) = \frac{\sum_{\substack{\text{for all SST used by } L_i \\ \text{where } DC=P \text{ or } O}} SST_i}{\sum_{\text{for all SST used by } L_i} SST_i} \quad (F2)$$

- The *Advancing the Discussion Indicator for the i th Learner ($ADI(L_i)$)* refers to the second abovementioned point and reflects learner's behavior in advancing the discussion taking into account a number of factors:
 - the messages that the learner L_i answered and s/he had to do so; that is, a collocutor expresses an opinion/proposal or a question referring to one of the L_i 's previous sent messages and expects an answer.
 - the messages that the learner L_i answered although s/he had not to do so; for example, in case a collocutor disagrees to L_i 's contribution or makes an inference

- and Li attempts to elaborate further on the collocutor's contribution by posing a question or expressing his/her agreement/disagreement, etc.
- the elaborations that the learner Li made on his/her own messages in order to give a clarification or a justification despite s/he was not asked to do so.

For each of the above factors, a weight is assigned by the teacher denoting the importance of each factor in the context of the underlying activity.

- The *Further Elaboration on a collocutor's view Indicator for the ith Learner (FEI(Li))* reflects that the learner Li not only acknowledges his/her collocutors' point of view but also wants to stress and elaborate further on the point under discussion and therefore promotes the discussion. The FEI(Li) is measured according to the formula (F3) which shows the mean number of the messages that learner Li has further elaborated on by filling in the "optional" text field.

$$FEI(Li) = \frac{\sum_{\substack{\text{for all SST used by Li} \\ \text{where UI = Op \& filled by Li}}} SST_i}{\sum_{\substack{\text{for all SST used by Li} \\ \text{where UI = Op}}} SST_i} \quad (F3)$$

The above three indicators contribute to the quantification of the *Promotion of Discussion Indicator for the ith Learner (PDI(Li))*, which shows learner's collaboration behavior in participating in a creative discussion. Each one of these indicators is partially contributing to PDI(Li) with respect to the corresponding weights assigned by the teacher and reflecting the degree of importance of each one in the context of a specific learning activity. More specifically, PDI(Li) is measured as in Formula (F4):

$$PDI(Li) = IDI(Li) * W_{IDI} + ADI(Li) * W_{ADI} + FEI(Li) * W_{FEI} \quad (F4),$$

where W_{IDI} is the weight denoting the contribution of IDI to PDI,
 W_{ADI} is the weight denoting the contribution of ADI to PDI,
 W_{FEI} is the weight denoting the contribution of FEI to PDI,

The above defined indicators have a complementary value in interpreting the interaction for each learner separately and making comparisons between the collocutors' contributions. They are estimated on the fly revealing the evolution of the cultivation of the desired skills and of learners' collaboration behavior in the context of the activity.

3.2 A Case Study

In the context of the formative evaluation of the ACT tool [4], an analysis of the learners' dialogues was carried out, in terms of the above defined learner indicators. In the following, we elaborate on two indicative cases in order to illustrate and explain the indicators. Figures 2 and 3 present raw data of two groups' contributions, aggregated for each learner separately as well as for the whole group, with respect to the corresponding discourse categories. Group G1 consists of two learners (usernames: tsourak and kourt, moderator: tsourak) while group G2 consists of three learners (usernames: kostop, bebelog and spanoud, moderator bebelog). The collaborative learning activity under consideration addressed learning outcomes of the Comprehension level, asking learners to identify as true or false five statements related to the subject matter of "Distance Education" and justify their answers. In this context, the teacher assigned high weights to the discourse categories of Proposal and Opinion, following the categories of Question, Reasoning and Clarification and afterwards the categories of Agreement and Disagreement. Low weights were given to the discourse categories of Inference, Motivation, Need and Social Comments.

As far as group G1 is concerned, in an attempt to interpret the learner indicators, as these are depicted in Table 1, we notice the following:

- The value of CSI indicator is greater for learner kourt than learner tsourak, meaning that learner kourt developed at a greater degree those skills addressed by the collaborative learning activity. This seems to be true as learner kourt made more proposals and opinions than learner tsourak (4 and 3 respectively), more agreements (3 and 2 respectively) and gave more reasons (2 and 1 respectively) (Figure 2).
- The above point is consistent with the value of IDI indicator, which denotes the mean number of the proposals and opinions made by a specific learner (for learner kourt, IDI indicator has greater value than for learner tsourak).
- Both learners seem to have equally attempted to advance the discussion by elaborating and contributing to their collocutor's point of view (the corresponding values of ADI indicator are very close). Having a close look at their dialogue, we observed that learner tsourak answered to more collocutor's messages than learner kourt (3 out of 5 and 2 out of 4 respectively) while learner kourt elaborated further on one of his proposals although he had not to do so.
- Learner tsourak reasoned for his agreements (value of FEI is 0,5; 1 out of 2) while learner kourt didn't justify his agreements at all (value of FEI is 0; 0 out of 3).
- Both learners contributed to a creative and productive collaboration as it results from the PDI indicator. The difference of the corresponding values is due to the difference in the values of ADI and FEI indicators.

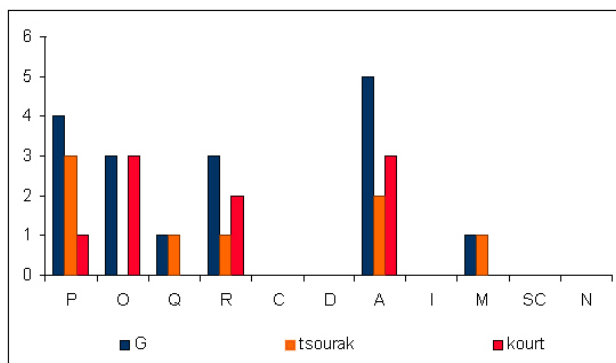


Figure 2. The contributions of each member of group G1 as they are presented in ACT

Group G1	CSI	IDI	ADI	FEI	PDI
tsourak	0,39	0,43	0,48	0,5	0,46
kourt	0,76	0,44	0,43	0	0,39

Table 1. The values of indicators for each member of the group G1

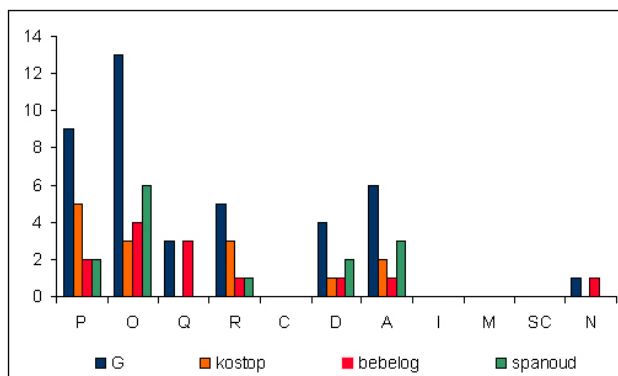


Figure 3. The contributions of each member of group G2 as they are presented in ACT

Group G2	CSI	IDI	ADI	FEI	PDI
kostop	0,68	0,57	0,07	1	0,41
bebelog	0,32	0,5	0,06	0	0,27
spanoud	0,45	0,57	0,19	0,6	0,42

Table 2. The values of indicators for each member of the group G2

As far as group G2 is concerned, we can reach to analogous conclusions in accordance to group G1. However, in the case of group G2, it is worthwhile noting the value of the indicator ADI with respect to the contributions of each member. Although, each member of the group G2 has exhibited skills in making proposals and expressing

opinions (the value of IDI is quite high for all members), they seemed to be reluctant to negotiate, questioning their collocutors and reach an agreement after a creative debate (the values of ADI are very low). Examining their dialogue, we observed that they could not agree on what answer to give to a specific question, and each one of them attempted to propose a solution without elaborating on his/her collocutor's point of view. In general, we can say, that all of them tended to express their opinion by making a new proposal instead of making an agreement to a collocutor's opinion even though they agreed with him/her.

4. Conclusions

In this paper, we present an approach to analysing learner interaction in the ACT tool, both quantitatively and qualitatively. The quantitative analysis aims to provide information about learners' contributions to the dialogue and the results are presented in a graphical form. The qualitative analysis aims to exploit various attributes regarding learners' contributions and investigate learner collaboration behavior in terms of (i) the cognitive skills that the learner develops with respect to the learning outcomes addressed by the activity, and (ii) promoting the collaboration by initiating/stimulating and advancing the discussion. A discriminative characteristic of the approach is that the teacher has the possibility to personalize the analysis process by defining weights to the attributes analysed denoting this way their importance with respect to the underlying activity. The illustration of the defined indicators with specific empirical data reveals that they give a valid evidence of learners' behavior during the collaboration process. However, the investigation of the validity of the proposed indicators with more groups of learners is considered necessary. Also, we plan to exploit these indicators in the development of guiding mechanisms, which will be adapted to learners' collaboration behavior.

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