It's all about time: towards the real-time evaluation of collaborative activities

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Abstract— **In this paper, we propose a method for the real time evaluation of collaborative activities. The method aims to classify collaborative activities using a memory-based learning model and to evaluate them using a reference set of pre-evaluated activities. The proposed approach uses time series to represent activities and classifies them regarding their similarity. In order to evaluate the results, the method is used as an automatic rater of collaboration quality and the ratings are compared to ratings of human experts.**

Keywords- ***CSCL; collaboration; evaluation; classification; learning analytics***

I. INTRODUCTION

Over the past years, research focused on the analysis and evaluation of collaborative activities. Many frameworks focus on capturing user interactions that indicate collaborative knowledge building, fruitful communication and successful coordination [1]. Log file and interaction analysis techniques are combined to support designers and orchestrators [2, 3], to provide feedback to users [4, 5] or to assess collaboration quality [6]. Time is a key aspect of the collaborative process that should be studied in detail while it is argued that, usually, frameworks do not take into consideration the temporal and sequential nature of joint activities [7].

In this paper we propose a method for the real time analysis and evaluation of collaborative activities. The method uses time series to represent user interactions and a memory-based learning model to evaluate new activities. The evaluation is carried out by classifying new activities using a reference set of pre-evaluated ones. The evaluation of the reference set was carried out by human experts with the use of a rating scheme. We argue that the results reflect qualitative judgments on aspects of collaboration. In the next section we present the proposed method and the study design, in section 3 we review the results and in section 4 we conclude to a discussion on findings and future work.

II. STUDY DESIGN AND METHODOLOGY

A time series can be defined as a collection of observations recorded sequentially through time [8]. Time series and ARIMA modeling were proposed for the analysis of joint activities of users who communicated asynchronously [9]. In the current study we use time series of user activity to compare collaborative practices regarding their similarity in time. We argue that practices of similar quality of collaboration will unfold through time in similar way and, therefore, they will be represented by similar time series. We believe that the method is suitable for real-time assessment since it does not require the completion of the activity and it is solely based on user activity that is captured by most groupware applications, with no need of additional coding.

The study deals with synchronous, collaborative activities within a learning context. The activities were carried out in a course of Computer Science in the University of Patras. Students worked in dyads to construct an algorithmic flowchart. The duration of the activity was about 90 minutes and each dyad collaborated over a groupware application (Synergo [10]). Synergo consists of two, shared spaces: a workspace for the construction of diagrammatic representations and a chat tool that facilitates communication. The application provides detailed log files of the activities for further use.

For the purpose of the study, collaborative activities are represented as time series. Time series are constructed by aggregated events of user activity within sequential time frames of the same size. The method takes into consideration that meaningful interactions indicating successful collaboration take place within certain time frames [11, 12]. This method was used in a previous study for the post-evaluation of collaboration quality [13]. The findings of the original study revealed that time frames of less than 60 seconds led to better results with respect to post-evaluation. This comes to an agreement with similar studies which show that meaningful interaction for synchronous activities takes place within time frames of 25 seconds [12]. The size of the time frame in the current study was 30 seconds. The selected value was calculated as optimal on an experimental basis for the current setting. Basic metrics of activity, such as the sum and rate of actions in shared workspaces and the sum and rate of users switching in activity, were used for the construction of time series. These metrics correlate highly to the quality of collaboration as shown in earlier studies [14].

The classification of collaborative activities is carried out by a memory-based learning model. The model TSCMoCA (Times Series Classification Model of Collaborative Activities) classifies an activity by comparing it to those within a reference set (Fig. 1). The collaborative activities are compared with respect to the similarity of their time series. The DTW distance (Dynamic Time Warping) is used as a similarity metric [15]. The reference set consists of pre-evaluated activities. Each entry in the reference set represents one collaborative activity and it can be perceived as a two-dimensional vector: one part for the time series of the activity and a second part for its evaluative value for quality of collaboration. The research hypothesis is that two collaborative activities which share similar time series will also share similar evaluative values. The sessions that reside in the reference set were evaluated by two expert evaluators with the use of a rating scheme [16]. The experts rated the activities on six dimensions using a 5-point-Likert scale [-2, 2]. The six dimensions are: Collaboration flow, Sustaining mutual understanding, Knowledge exchange, Argumentation, Structuring the problem solving process and Cooperative orientation. The overall value for the quality of collaboration (CQA) was computed as the average value of the ratings on the six dimensions.

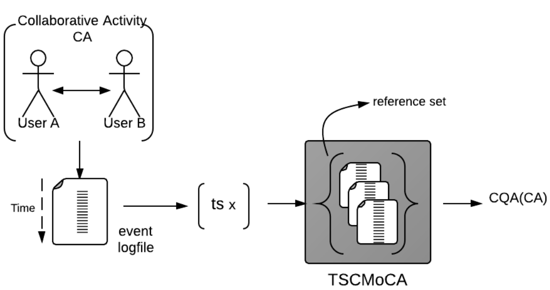

Figure 1. The evaluation process of a collaborative activity CA using the model TSCMoCA.

The purpose of the study is twofold: (a) to confirm that the time series classification method can be used for real time evaluation and (b) to define the length of activity log files required for efficient evaluation. The method is used on various time instances while the activity is still unfolding to evaluate the quality of collaboration. In total, 210 collaborative sessions are classified with respect to their collaboration quality on certain time instances an throughout the duration of the activity. The classification is conducted on the 25 and 40 minutes (i.e. on about the first quarter and first half of the activity) and after its completion.

III. Results

In order to evaluate the method, we use the model as an automatic rater. The collaborative activities are evaluated regarding the quality of collaboration (CQA) and each one of the six collaborative dimensions, as defined by the rating scheme. The ratings of the model are compared to the ratings of human evaluators. A correlation and error analysis is conducted after this comparison. The Spearman’s rank correlation coefficient is used to assess the predictive validity of the method and the mean absolute error (MAE) to estimate its accuracy. In Table I we present the results of the rating on the quality of collaboration (CQA) for t_i = [25 minutes, 40 minutes and total duration]. Table II shows the results of the rating for each one of the six collaborative dimensions for t_i=40 minutes from the beginning of the activity.

TABLE I. Correlation and error analyses results for the real time evaluation of the Quality of Collaboration

	25 minutes	**40minutes**	**Total activity (≈90minutes)**
Correlations ($p<0.05$)	0.27	0.51	0.59
Mean Absolute Error	0.99	0.94	0.91

In all cases, the ratings of the model correlate significantly ($p<0.05$) with the ratings of human evaluators. Weak correlations appear when evaluation takes place 25 minutes after the beginning of the activity. Results show significant improvement when the evaluation is carried out 40 minutes after the beginning of the activity where the ratings of the method and human evaluators correlate highly. The mean absolute error is less than 1 in all cases, for a 5-point scale. The performance improves fast within the first half of the activity while it improves less for the second half. Therefore the evaluation of the quality of collaboration (CQA) could be carried out on the half of the activity with no significant loss with respect to the result of the post-evaluation procedure.

The method is further used to evaluate collaborative activities on the six collaborative dimensions, as defined by the rating scheme [16]. The evaluation was carried out for the first half of the activity (40 minutes). The ratings of the model significantly correlate with the ratings of human evaluators on all six collaborative dimensions ($\rho>0.4$, $p<0.05$) and the mean absolute error is slightly over 1 for five out of six dimensions. The proposed method performs effectively for dimensions that reflect communication and joint information processing on a low level (Collaboration flow, Knowledge exchange). For more complicated structures (Argumentation and Structuring the problem solving process) the model ratings show low correlation and high error comparing to the ratings of human evaluators. Simple metrics of activity can effectively describe low level theoretical constructs. However for more complicated constructs qualitative analysis is necessary to provide a clear picture of collaborative mechanisms [17].

TABLE II. CORRELATION AND ERROR ANALYSES RESULTS FOR THE REAL TIME EVALUATION OF COLLABORATIVE DIMENSIONS

Collaborative Dimensions	Correlation	MAE
Collaboration flow	0.53	0.92
Sustaining mutual understanding	0.42	1.02
Knowledge exchange	0.5	1.17
Argumentation	0.44	1.25
Structuring the Problem Solving Process	0.46	1.17
Cooperative orientation	0.47	1.07

IV. CONCLUSIONS AND FUTURE WORK

This paper presents a method for real time analysis and evaluation of collaborative activities. The evaluation is carried out by a memory-based learning model. Each activity is classified and evaluated by comparing its similarity -in terms of time series of activity- to a reference set. The method was tested as an automatic rater and the results were validated by comparing the ratings of the method to ratings of human experts. The ratings correlated highly for most cases to the ratings of human evaluators. The performance of the method is improved as the duration of the ongoing activity increases. The method performs effectively when the evaluation is carried out in the middle of the activity and the results are similar to the results obtained for post-evaluation on the whole duration.

The proposed method was studied for the case of dyads that collaborate synchronously on a domain-specific task. Additional factors such as the team size, the nature of the task and the type of communication, must be further explored. In future work, we plan to implement a tool to support class orchestration and test it in the classroom. The application of the method in a real class scenario does not intend to substitute the teacher but rather help to empower her practice.

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