# Interaction Analysis as a Tool for Supporting Collaboration: An Overview

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**Abstract.** This chapter constitutes an overview of logfile-based interaction analysis techniques that can be used for the support of Computer Supported Collaborative Learning (CSCL) activities. Interaction analysis is central in the study of CSCL activities, since in such activities through interactions between partners the state of evolving group knowledge is communicated. This interaction is facilitated by tools that allow logging of events that take place, capturing thus information about the content and the process of collaboration. Automated analysis techniques of this information can be developed. The objective of this analysis is often to support participants, in several ways: explicitly, by providing feedback to them in order to regulate their practices, or by making adaptive changes to some aspects of the collaborative setting; or implicitly, by making available to them representations of their activities. This chapter presents the most common approaches used in interaction analysis, while it particularly emphasizes recent innovative efforts to reap the advantages of machine learning techniques in order to overcome common shortcomings of previous approaches.

## 1 Introduction

Computer Supported Collaborative Learning (CSCL) constitutes a field of research and practice in the broader context of study and development of educational technologies. This research field is inspired by multiple research backgrounds, as it covers a wide range of activities and engages a multi-disciplinary community. In this context, an approach used extensively is the analysis of interaction (Jordan and Henderson, 1995).

CSCL constitutes a suitable field of applying analysis of interaction since, in collaborative learning, the state of evolving knowledge must be continuously displayed by collaborating participants with each other (Stahl 2002). Therefore, what one participant communicates with others is accessible to researchers, providing thus an objective source for analysis (Dillenbourg et al. 1995). Analysis is based on such observable interactions rather than measures of learning outcomes, models of students' mental representations, or internal cognitive processes, as is the

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case with other paradigms of instructional technology (Koschmann, 1996). Moreover, the tools that mediate collaboration allow for the logging of events that capture aspects of the content and the process of interaction.

Based on this recorded information, automated or semi-automated analysis techniques can be developed that are used for supporting the collaborative process. This support can be provided in different ways: explicitly, by providing feedback to the participants in order to regulate their practices, or by making adaptive changes to some features of the collaborative setting; or implicitly, by making available to the participants representations of their activities. This support of the collaborative process may be important in many cases, as it can scaffold and enhance collaborative learning.

In order to successfully support and guide collaborative learning activities, and preferably in a dynamic, adaptive way, it is necessary that some knowledge of significant aspects of the process, as it evolves through time, is obtained. This is not a trivial task and in traditional settings depends on the knowledge, experience and intellect of human tutors that intervene to the process accordingly. However, interaction analysis for the study of collaborative processes and the technological collaborative facilities can offer possibilities for automatic evaluation of collaborative processes. Collaboration tools usually keep logs of events of the users' interaction and maintain them in suitably structured logfiles. These entries can then be manipulated and lead to targeted metrics that indicate meaningful aspects of collaboration, interaction, or learning, a process that is conceptualised and discussed in the framework presented later in this chapter.

This chapter constitutes an overview of logfile-based interaction analysis techniques that can be used for the support of CSCL activities. We start with a short description of general issues of analysis and evaluation of CSCL activities, followed by an introduction of a framework of the different stages that interaction analysis usually follows. The most important approaches in CSCL literature of automated interaction analysis based solely on logfile entries are then discussed, including cases where participants of the CSCL processes are forced to annotate parts of their interaction themselves. Such approaches were popular especially in the first years of the establishment of the research field, they have been, however, extensively criticised, the former because they may lead to "surface" metrics that lead to poor indications of collaborative practices, and the latter because they are likely to influence the collaborative process in ways not desired by their designers. The subsequent section is devoted to the most common interaction analysis techniques for which human intervention in the process of analysis is necessary, and that are nonetheless formalizable and suitable to be used for the support of CSCL processes. Such approaches can lead to analysis of collaboration on a deeper level, since they are based on subtler evaluations accessible to the human intellect that can not be conveyed by technologically feasible formalisations. However, such techniques are often arduous and time-consuming and cannot be used for the support of CSCL activities on a timely manner. Finally, the article concludes with thorough discussion of recent advances of automated interaction analysis that try to combine advantages of the two general aforementioned categories of interaction analysis techniques, while they aim at overcoming their shortcomings. These approaches use deeper-level evaluations of CSCL activities conducted by human analysts in order to train models of interaction analysis based on automated logfile captures. It is expected that the latter approaches would offer qualitatively advanced opportunities for the meaningful and efficient use of automated interaction analysis for supporting CSCL activities.

## 2 Analysis and Evaluation for the Support of Collaborative Learning Activities

CSCL covers a wide range of educational activities many of which are characterised by extended complexity. For this reason, the study of CSCL activities follows several approaches and traditions of research that can be discriminated in several ways. A major distinction that applies to the case of CSCL as well as to most research disciplines regards the distinction between *basic* and *applied research*. This distinction is determined by the objectives of a research study. In the first case, the goal of research is to gain insight into CSCL activities themselves in order to build new knowledge in the field, whether this is done by descriptive, qualitative studies of detailed episodes of collaboration, or by testing experimental hypotheses in order to understand the role of significant variables that influence and affect collaboration and its possible learning outcomes (Stahl et al. 2006). The first body of studies in CSCL research focused on the comparison between the efficiency of the new educational approach and traditional methods of instruction, in order to prove that the new approach was worth pursuing in terms of the learning benefits that it can offer and the efficient use of resources possibly spent in an institutional context (Dillenbourg et al. 1995). As the field was evolving, it became evident that success in the field of study was subject to multiple and extensively intermingled factors. Therefore, the next trend of basic research put more emphasis on the conditions under which the CSCL approach can be fruitful. A number of factors of different kinds can influence a CSCL process. The means of communication (synchronous vs. asynchronous collaboration), spatial constraints (co-located vs. distant collaboration), the structure of the activity, the profile and knowledge background of learners and the way they form collaborative groups are some of the factors that can shape the flow and the outcome of a CSCL process (Dillenbourg et al. 1995).

At another level, in addition to CSCL basic research proper, there is a strong need for development of efficient and effective analysis and evaluation techniques for collaborative activities, suitable for practical uses in real-world settings. We refer to this general approach as applied research. Evaluation can be discriminated from research in general or analysis in that it intends to lead to judgments on the activity, whereas research's focus is mainly to describe, explain, or predict. Moreover, analysis is descriptive, whereas evaluation is normative. Analysis is conceived as of lower level than research and can inform the latter without necessarily producing axiological judgments, although it may be influenced by some form of implicit values. The main general objectives of applied CSCL research are:

- to inform the design of new tools that mediate or analyze / evaluate interaction
- to inform new pedagogical and organizational designs of CSCL activities
- to provide teachers with the means of making assessments of students' performance (by evaluating not only the outcome of a CSCL activity, but the process through which learning gains may be achieved)
- to intervene to the collaborative process in ways that are deemed beneficial for participants

The tools that mediate or analyze collaboration are crucial for the shaping of CSCL and CSCL research respectively, as is the design of tasks that students are asked to engage with, and the shaping of the broader setting of a CSCL activity. In cases where this kind of objectives necessitates an evaluation approach, this can be of a formative or summative variety. Formative evaluation is conducted in some intermediate part of the process and is concerned with the improvement of the object of study, whereas summative evaluation takes place after the end of the studied phenomenon and intends to examine its overall effects. A specific case of the use of summative evaluation regards the need of assessing students participating in CSCL activities in some educational context in ways appropriate for this new educational approach. An example of formative evaluation relates to timely feedback that can be given to students of a CSCL process based on their collaborative practices.

The latter case relates to the goal of many CSCL analysis and evaluation studies that aim at monitoring the progress of the collaborative process and at allowing for timely adjustments to be made. An overview of such approaches constitutes the object of this article. The need for supporting collaborative processes arises from observations that effective CSCL activities need, in many cases, to be designed in such a way as to provide for adequate feedback that scaffolds the learning process. It has been found that simple participation in a collaborative activity does not guarantee that learners gain any benefits (e.g. Salomon and Globerson 1989), as collaborative learning activities can be fruitful, and preferable to more traditional approaches, under specific circumstances.

Interventions in collaborative processes can be made by tutors and supervisors, by the tools that mediate interaction, or by both. A categorization of CSCL tools regarding this issue has been proposed by Jermann et al. (2001) and Soller et al. (2005), distinguishing CSCL tools into monitoring, mirroring, and guiding tools.

*Monitoring tools* refer to the elementary facilities that a mediating CSCL tool must provide. The basic objective that such a tool must fulfill is the consistent transmission of one user's actions to all their partners. The tool must provide awareness (Dourish and Bellotti 1992; Rodden 1996; Gutwin and Greenberg 2002) of each user's actions, coordinate their actions, and ensure technologically seamless communication. Monitoring tools do not support any kind of analysis.

*Mirroring tools* or *meta-cognitive tools* extend the scope of CSCL tools by integrating analysis facilities. Such tools process data that are stored in logfiles they sustain, and supply the results of processing to collaborating participants and, possibly, to supervisors that may intervene in the process, and to researchers. This way, learners can use the results of analysis in order to assess the extent of collaboration of their group or their personal contribution to the process. Analysis data are thus reflected (or "mirrored") to the students, who are responsible for the interpretation of results and the adaptation of their practices so that they become beneficial for the whole process.

*Guiding tools* go a step further: they use analysis results, for advising or tutoring the students. Analysis results are not simply reflected to the users in order to be interpreted by them, but the system intervenes directly, trying to substitute or complement the role of a human tutor, and inevitably, evaluates the practices of the students at a given time. This way, the learning process is suitably adapted, based on the performance of the participants.

The support of CSCL activities that is of interest in this chapter refers to mirroring and guiding types of CSCL tools, as the first case of monitoring tools does not involve any kind of analysis or evaluation. The *meta-cognitive* character of mirroring tools concerns the existence of awareness about cognitive aspects of the collaborative process so that participants control and self-regulate their current practices in order to overcome perceived shortcomings (Brown 1987). It was originally perceived at the level of just an individual but this can also be generalized at the group level, based on conceptualizations of distributed cognition (Salomon 1995). Meta-cognition is supported by computer tools by automated interaction analysis processes, as will be discussed later in this chapter.

Guiding tools support the collaborative process in more interventionist ways and there can be several conceptualizations of their use. They can be thought of as scaffolding tools. In more conventional educational settings, scaffolding refers to targeted interventions by tutors and other educational agents that aim at changing the problem at hand so that the learner is able to perform tasks that would otherwise be out of their reach (Reiser 2002). There is a long history of theorizing related to the concept of scaffolding, from Vygotsky's work on the "zone of proximal development" (Vygotsky 1930/1978) to the concept of cognitive apprenticeship (Collins et al. 1989). Moreover, paradigms of instructional technology such as Intelligent Tutoring Systems (that eventually aim at substituting a human tutor with a computer-based, automated one) are extensively based on the concept of scaffolding (Shute and Ptsotka, 1995). Scaffolding usually targets at task-related issues in most single learner educational approaches, but in collaborative learning, scaffolding may also focus on the improvement of the practices of students that regard the process per se, their collaborative skills, their contribution to teamwork etc. It is thus adaptive in the sense that it behaves dynamically depending on knowledge of significant aspects of the collaborative process as it evolves through time. It may also refer to simple aspects such as the need for balanced interaction between the students in terms of contributions to the communicative process, or to subtler interventions that shape the whole educational design of the CSCL activity. In the latter case, the concept of scripts (Kollar et al. 2006) plays a crucial role. Scaffolding may concern changes of the whole design of a CSCL activity implementing therefore the case of adaptive scripts (Rummel and Weinberger 2008), and part of this dynamic behaviour can be based on tools that are informed by interaction analysis techniques. The least task-specific cases of scaffolding are of interest in this article that deals with the utilisation of interaction analysis techniques for that purpose.

## 3 A Framework for Interaction Analysis and Evaluation Techniques

The typical process of logfile-based interaction analysis can be formalized in a multiple stage process according to the representation of Fig. 1.

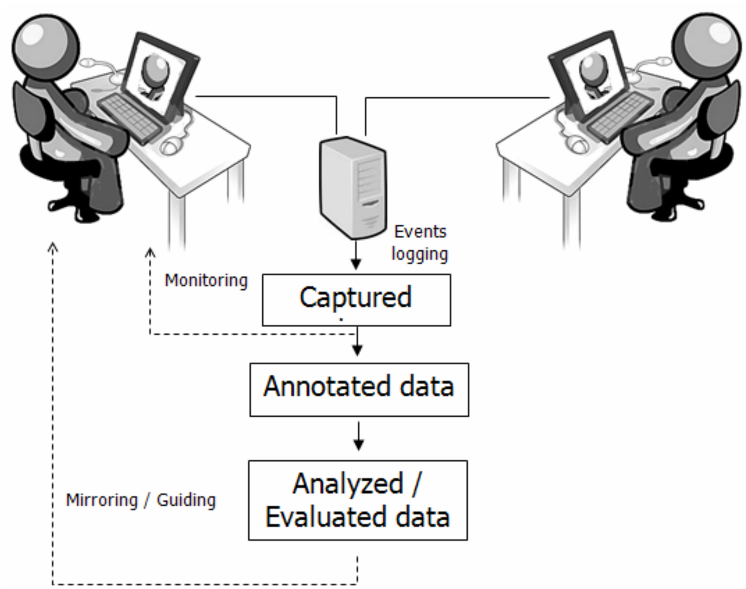


**Fig. 1** A framework describing logfile-based interaction analysis

The CSCL mediating tool collects interaction data that refer to events captured and stores them in a logfile. Each recorded event is annotated according to a predefined typology, and related to the user who has generated it, the time when it occurred, and other aspects that convey additional information. Additional annotation may then be applied at another level. These annotated data are processed and analyzed so that meaningful results are obtained. The outcomes of this processing are then interpreted by the researcher or automatically by the tool, and can be used to reshape the collaborative process whether this regards automatic changes in the tool's behavior or the explicit provision of feedback to learners.

As stated above, in the first stage, CSCL mediating tools keep logs of interaction events that users generate with them and automatically assign them to categories. Of major importance is the typology used that describes the types of events logged. An example of such a typology is defined in OCAF (Object-oriented Collaboration Analysis Framework) (Avouris et al. 2003). This framework was created for the meta-description of data captured by CSCL tools in the case of collaboration through chat and shared workspace. In such cases, students collaborating in small groups create a joint model that constitutes a solution to a given problem. Typical events reported refer to the posting of chat messages and the creation and manipulation of objects in a shared workspace. OCAF serves for an integrated description of events generated through such means of communication. Workspace-related actions are automatically annotated according to predefined rules integrated in the tool's functionality. For example, the meta-description of the insertion of a new object in the shared workspace can be done straight after the action is recorded and propagated to all collaborating users. However, in the case of chat-related events, such automatic annotation is not always possible and usually demands the involvement of human annotators, as the meaning of natural language cannot be easily extracted by the machine. One way of bypassing this problem is to render the users responsible for annotating their own messages. This can be done explicitly, by necessitating that they associate each message they sent with a specific type (Barros and Verdejo 2000); or implicitly, by providing them with a set of "sentence openers" that are transparently related to specific categories (Dimitracopoulou and Petrou 2003). Yet the transfer of message annotation duties to participants of a learning process may significantly influence the activity under study, as it may inhibit fluent flow of interactions, shifting focus from cognitive to meta-cognitive tasks.

The last stage of interaction analysis, concerning the analysis and evaluation of annotated data is crucial for the process. It refers to processing of the original dataset that leads to metrics of interaction, informative of significant properties of the collaborative process. Alternatively, the analysis may be of a more interpretative nature, but this model mostly refers to qualitative, highly formalized interaction analysis that is bound to be more useful for the practical support of collaborative learning activities. This stage also involves the interpretation applied to the results of analysis, which is based on judgments about the collaborative process and possibly leads to guiding actions that reshape the process in ways desired by its designers. In the case of the use of metrics of interaction such interpretations may be based on solid rules regarding threshold values of metrics or other criteria that lead to decisions that the tool makes that determine the way it should intervene in the process.

Based on this general conceptualization, the rest of this chapter presents the main approaches to interaction analysis techniques, shown in fig. 2, that are relevant for the provision of support to the collaborative process in practical terms. Such techniques are distinguished in three main categories: fully automated techniques that only build on logfile entries of interaction events in a top-down manner, techniques that necessitate that human agents are engaged in analysis, and techniques that become fully automated only after the logfile-based metrics they use have been trained on deeper-level evaluations conducted by human analysts.

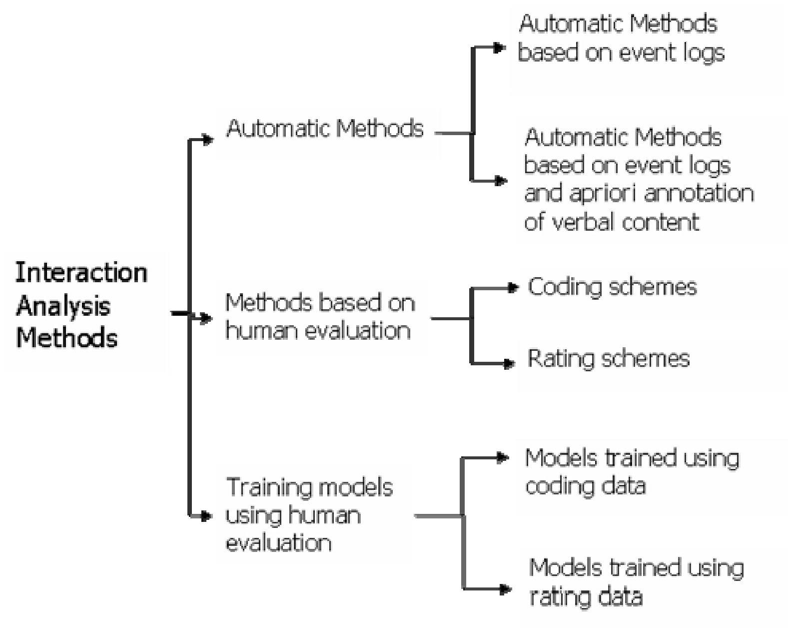


**Fig. 2** Overview of interaction analysis techniques

# 4 Top-Down Automatic Interaction Analysis Techniques

## *4.1 Automated Interaction Analysis Based on Event Logs*

In the first years of the development of the CSCL research field, analysis that was based on measures of automated logfile entries in a top-down manner was particularly popular. For example, numerous metrics indicating the symmetry in collaborative interactions (i.e. the balanced amount of contributions from all participants) have been developed in CSCL or other relevant research disciplines (Hiltz et al. 1989; Warschauer 1996; Constantino-Gonzalez and Suthers 2000; Fitze 2006; Jermann and Dillenbourg, 2008; Marshall et al. 2008; Buisine 2010). In other cases, more sophisticated metrics were proposed: e.g. in the frame of the Synergo analysis tools, Avouris et al. (2004) have developed a set of metrics that reflect interesting aspects of interaction, such as a Symmetry, a Balance, a History, and a "Collaboration factor". Schümmer et al. (2005) have similarly developed a metric that reflects the volume of interaction activity throughout a collaborative process, based on calculations of actions that are characterized by spatial or temporal proximity. Other studies concern calculations of the structure of threads in asynchronous discussions (Simoff 1999; Hewitt 2003), and associations between participants of a collaborative activity applying Social Network Analysis (SNA) (Scott 2000; Wasserman and Faust 1994) using measurements of event logs. SNA has gained wide popularity and several such studies have been conducted for asynchronous CSCL activities involving large groups or communities of participants interacting through file sharing systems (e.g. Martinez et al. 2003; Nurmela et al. 1999), asynchronous discussion fora (e.g. De Laat, 2002; Lipponen et al. 2001), or emailing systems (e.g Reffay and Chanier 2003).

Totally automated metrics, such as the ones discussed above, can be reflected back to the participants in order to inform them on their collaborative performance. Metrics of participation may constitute the input of suitably visualized metacognitive artifacts, such as the ones developed by Jermann and Dillenbourg (2008) and common visualizations of social network analysis, or even for explicitly guiding the collaborative process (Constantino-Gonzalez and Suthers 2000).

## *4.2 Automated Interaction Analysis Based on Event Logs and a Priori Annotations of Verbal Content*

All the approaches mentioned in the previous section use event logs to calculate metrics of interaction. They do not involve any systematic analysis of the verbal content of interaction and do not involve human-made annotations. One way to enrich the information to be analyzed is to take into account to some extent verbal content of e.g. exchanged communication messages without resorting to the assistance of human evaluators. This can be done by enforcing the participants of the collaborative process to explicitly or implicitly annotate their verbal actions. For example, when using the DEGREE tool for asynchronous online discussion, participants have to associate each message they send with a specific predefined message type (Barros and Verdejo 2000). Moreover, the types of annotation available to participants are dynamically defined, based on types assigned to previous postings and predefined graphs of desired sequences of types of such contribution. In addition, several metrics are calculated and are integrated into a fuzzy reference procedure that produces ratings of collaboration. This way, the mediating tool guides the collaborative processes based on fully automated analysis of interaction.

If having participants of the collaborative process annotate messages they send themselves is considered to be too intrusive for the ecology of the collaborative process, a “milder” approach involves implicit ways of a priori annotating verbal interaction. Participants can be provided with a set of “sentence openers” when they want to post a message, which are transparently related to specific categories (Dimitracopoulou and Petrou 2003). This can be designed on a voluntary (e.g McManus and Aiken 1995; Baker and Lund 1997) or a mandatory basis (e.g. Robertson et al. 1998; Soller et al. 2002).

This extra information resulting from annotations of verbal content of interaction constitutes a richer source for automated analysis than simple logfile counts. Therefore, several tools and studies conducted reaped the advantages of the application of more sophisticated artificial intelligence techniques for automated analysis. Such techniques regard finite state machines (McManus and Aiken 1995; Inaba and Okamoto 1997), fuzzy inferencing (Barros and Verdejo 1999), rule learning (Katz et al. 1999), decision trees (Constantino-Gonzalez and Suthers 2000), plan recognition (Muehlenbrock and Hoppe 1999), and Hidden Markov Models (Soller 2002; Soller and Lesgold 2003) (Jermann et al. 2001). The purpose for all these advanced calculations was that collaborative systems would provide timely feedback to the collaborative process.

## 5 Interaction Analysis Techniques with the Aid of Human Evaluators

As stated in the previous section, it is not always possible to fully automate the annotation and analysis process described in Figure 1, and obtain meaningful results. The difficulty of formalizing verbal content of interaction, or the side-effects of obligating participants to annotate verbal content themselves (explicitly or implicitly), often requires the involvement of human agents in the annotation and analysis process. Of course, this approach misses the opportunities for totally automated and timely analysis of interaction. This section focuses on two approaches of interaction analysis techniques that necessitate the interference of human agents in analysis: the application of *coding schemes* (referred as *content analysis* in many cases) involves human intervention in the stage of annotation, whereas the application of *rating schemes* (or rating scales) skips the annotation stage and renders human raters responsible for overall evaluation. Both approaches are considered as techniques that produce outcomes that can be useful from several methodological standpoints. Moreover, they are formalisable and closer to previous quantitative approaches than other deeper-level qualitative analysis approaches.

### *5.1 Coding schemes*

As discussed, the verbal content of messages and postings, standing at the core of most CSCL interaction, cannot easily be manipulated and categorized in automated ways. Message content is highly contextual and elliptical, while the structuring of subsequent messages is of increased complexity when compared to face-to-face interactions (Garcia and Jacobs 1999; Herring 1999; O'Neil and Martin, 2003; Suthers et al. 2003). Therefore, formalizations of CSCL verbal content that can render analysis automatable cannot easily lead to useful results that take deeper aspects of collaboration into account. Moreover, the alternative approach of forcing participants of a CSCL session to use sentence openers can influence the process in not desirable ways.

It is therefore necessary that in many circumstances, human agents apply appropriate, additional annotations to the recorded data. Often, this involves the application of theoretically derived coding schemes such as the one developed by Gunawardena et al. (1997). This technique is generally known as *content analysis,* which is defined as "a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding" (Krippendorf 1980; Weber 1990). Its main goal is to extract from the complexity of exchanged messages in a CSCL process indicators related to basic aspects of interaction, collaboration, or learning.

There is a diversity of such indicators in the CSCL literature, depending on the specific research objectives and research theory. A first approach in the field by Henri (1992) dealt with indicators of cognitive and meta-cognitive skills. Newman et al. (1997) examined indicators of critical or deep thinking in contrast to surface thinking (Garrison 1991). Later studies followed a socio-constructivist framework for the study of knowledge co-construction (Gunawardena et al. 1997; Veerman and Veldhuis-Diermanse 2001).

A set of indicators forms a protocol of annotation of dialogues that is accompanied by an established theoretical framework. Such a scheme should be easily applicable by appropriately trained researchers. Some of the most influential coding schemes have been proposed by Gunawardena et al. (1997) for studying CSCL activities in asynchronous discussion fora, Garrison et al. (2000) in similar settings but covering in addition aspects of tutor participation in the CSCL process, and Baker et al. (2003) in synchronous CSCL activities with the use of an argument graph tool with an integrated chat tool.

The unit of analysis of the coding process can vary according the theoretical underpinnings of the schemes and the specificities of the interaction media used. The most common choices refer to the *message* (or *event* in another medium if applicable), the *thematic unit*, and the *illocutionary act*. In verbal content analysis, these types of units correspond to aspects of the syntactic structure of a message, its thematic content (in a less objectively defined way), and the structuring of dialogue according to *speech act theory* (Howell-Richardson and Mellar 1996; Searle 1979) respectively.

Since annotations in content analysis are applied by human agents, some extent of subjectivity in the assignments of units of content into categories is unavoidable. It is therefore necessary that reliability is assured by involving several suitably trained researchers in the annotation of the same content in parallel. A high level of concordance between coders constitutes an indication that the process is reliable. Several measures have been established for the testing of inter-coder reliability, such as a simple percent agreement, Holsti's measure (Holsti 1969), Scott's pi (Scott 1955), Cohen's kappa (Cohen 1960), and Krippendorff's alpha (Krippendorf 1980). A threshold has been empirically established in the research community for each measure, for the results to be considered acceptable.

The results of the application of a coding scheme to data of CSCL activities can be used in many ways. They may be used in a qualitative manner, serving just for reflecting aspects of collaboration and condensing related information, describing communication and interaction. However, the use of content analysis that is most relevant to the scope of this chapter, and can reap the benefits of technology to support a collaborative process, is to quantify attributes of verbal interaction that serve for further automated analysis.

Informed interventions in the collaborative process in this case are still possible in asynchronous longer-term activities, or series of synchronous collaborative sessions, that last long enough so that the time-demanding analysis of the data is feasible.

## 5.2 Rating schemes

A *rating scheme* or a rating scale is “a measuring instrument that requires the rater or observer to assign the rated object to categories or continua that have numerals assigned to them” (Kerlinger and Lee 2000, p. 736, cited in Meier 2005). Rating schemes are discriminated from coding schemes in that they are used to make a judgments on a larger set of data at a time, and are based on the knowledge and critical skill of the human agent that applies them, whereas coding schemes usually demand from the coder to neutralize the process by following strictly defined rubrics (Kerlinger and Lee 2000). Rating approaches are thus normative, and refer to evaluation in the stricter sense of the term, whereas content analysis approaches are usually descriptive and regard analysis, unless further statements related to their place in a research process are made. A rating approach can either cover all the stages of the logfile-based interaction analysis framework of Figure 1, or it can cover just the stages of annotation and analysis, since interpretations, may be based on further elaborations.

Rating scales may be intuitive, without any strict theoretical grounding, or concept-oriented (Langer and Schulz von Thun 1974). Concept-oriented rating schemes require precise definitions of the concepts that determine the rating grades and provide information on the means of correctly applying the process (Guilford 1954). Other facilities such as the use of anchoring examples or handbooks that provide guidelines for the correct conduct of the rating process are also deemed necessary (Meier 2005).

However, even if the rating process is done in a rigorous and systematic way, it still relies on judgments of human agents that cannot be totally objective. Therefore reliability testing of rating processes is even more important than in the application of coding schemes. In this case, reliability refers not only to the extent of exact agreement between the grades different raters apply, but to how close they are in the range of the scale. The most commonly used measures of inter-rater reliability are *intra-class correlation* (ICC; Shrout and Fleiss 1979) that measures the explained variance based on the ANOVA-model, *adjusted ICC* that, in addition, discards any differences in raters’ mean values, *Cronbach’s alpha* (Cronbach 1951), *Spearman’s rho* and *Kendall’s tau* (Wasserman 2006) as correlation factors that can also give an interesting approximation of concordance. Thresholds of acceptable concordance for each measure have been proposed as empirical conventions (e.g. ICC scores higher than .7 are considered to signify good inter-rater reliability; Wirtz and Caspar 2002, cited in Meier 2005; 0.6 is considered acceptable for Cronbach’s alpha; George and Mallery 2003).

Several studies have applied the rating scheme technique in the CSCL field. Järvelä and Häkkinen (2003) developed a concept-oriented scale for assessing the level of perspective taking (Selman 1980) in asynchronous online discussions. Meier et al. (2007) developed a rating scheme for the multi-dimensional assessment of collaboration quality in synchronous interdisciplinary problem-solving through videocoenfencing systems. This scheme was also adapted in order to be suitable for another CSCL setting (Kahrimanis et al. 2009), without sacrificing its core conceptual rationale and operational properties. The latter version of the scheme was used in a pilot study that involved the provision of adaptive feedback to collaborating dyads. Students received feedback from tutors in dimensions of collaboration in which they had poor performance in prior similar sessions (Meier et al. 2008).

# 6 Trained Automatic Interaction Analysis Based on Human Evaluations

As discussed above, interaction analysis techniques sometimes fall short of providing empirically meaningful indications of important aspects of collaboration without the intervention of human evaluators. Measures of automatically logged events cannot often account for deeper level aspects of collaboration.

On the other hand, human-based evaluations are usually arduous and time consuming, especially in the case of content analysis, and miss the advantage of supporting the collaborative process in real time.

One way to proceed to new, qualitatively different automated interaction analysis tools is to use human evaluations as an external point of reference to the values that automatic interaction analysis leads to, and estimate metrics of interaction in a way that they can reflect aspects of collaboration proved to be meaningful by human analysis. The necessary precondition for pursuing such an approach is that the results of human analysis are formalizable, as is the case with coding and rating schemes.

## *6.1 Automated Interaction Analysis Trained on Coded Data*

Recent advances in CSCL research regard efforts to support the coding process of content analysis in automated ways. In contrast to aforementioned approaches to annotate verbal interaction during the ongoing collaborative process (e.g by forcing participants to annotate their actions), the aim in this case is to provide trustworthy automated content analysis without any unintended influence on the collaborative activity itself.

A technically simple approach to that problem is to define *keywords* or *key phrases* that are linked to specific categories of a coding scheme. This approach is followed in the work of Law et al (2007), who have developed an analysis tool that facilitates the process of content analysis by highlighting specific predefined keywords or assigning preliminary codes to segments of data that are supposed to be eventually annotated by human analysts. Erkens and Janssen (2008) follow a similar rationale using *discourse markers* or *clue phrases*, which are used for segmenting and mapping dialogue content into predefined categories. Both approaches constitute encouraging attempts to automate the content analysis procedure (which can otherwise be extremely tedious). They are, however, tightly related to specific a priori defined coding schemes, and more importantly, the rationale of annotation is defined in a top-down way, significantly influenced by aspects of the technical manipulation of dialogue content.

An alternative approach, able to overcome some of these shortcomings, was proposed by Rosé et al (2008) who took advantage of recent advances in text classification technology in computational linguistics to apply machine learning techniques to a large CSCL corpus that had been analyzed by human coders using a theory-based multidimensional coding scheme (Weinberger and Fischer 2006). In this way, annotations applied automatically are not determined by a priori defined rules, but are trained on empirical annotations by human evaluators.

The study involved approximately 750 university students that mostly collaborated in groups of three through a discussion forum. Their task was to apply theoretical concepts from Attribution Theory (Weiner 1985) to specific case problems, while following (in some cases) a predefined script for collaboration that emphasized mutual feedback between participants (Weinberger et al. 2005).

The resultant dataset, comprising 250 discussions in the forums, was object to content analysis. Appropriately trained coders categorized each segment using the coding scheme (Weinberger and Fischer 2006). The unit of analysis for assigning categories to segments of dialogue was not defined by strict linguistic structural properties, but was related to the information conveyed in dialogue (closer to a thematic unit), following the approach of Weinberger and Fischer's (2006) coding scheme.

A part of the whole coded corpus consisting of 1250 coded segments was used to train machine learning algorithms that learnt rules and applied them automatically to segments of data that had not been annotated by human evaluators. The algorithms were based on mappings between a set of input features and a set of output categories. Input features included punctuation marks, unigrams and bigrams (single or pairs of words), part-of-speech bigrams (pairs of grammatical categories), line length counts, etc., while appropriate practices for other technical aspects of verbal content such as the omission of rare words or the grouping of similar words (stemming) were also applied. Starting from an already defined segmentation by human evaluators, researchers pursued two basic approaches to the development of machine learning models: a feature based approach, such as the one described above, and an algorithmic approach. Results were encouraging ranging from very good for certain dimensions of the scheme, to more problematic scores for other dimensions (Rosé et al 2008). The work resulted also in the development of the TagHelper application, which can be used for content analysis type evaluation approaches for other CSCL settings as well.

Although this significant research work can be thought of as being still in a an evolving phase, encouraging results obtained so far have initiated a new thread of automated interaction analysis tools, which, if suitably improved, can lead to automated support of CSCL processes that can stand on comparable performance to human agents. Provided that estimation scores are further improved, the development of specified meta-cognitive aids available in real time, the provision of targeted timely feedback, and the handling of large datasets would be possible following the discussed here approaches.

## *6.2 Automated Interaction Analysis Trained on Rated Data*

Automated interaction analysis using coding schemes (or automated content analysis), stands in parallel to following a similar approach when using rating schemes. The advantages of automated techniques involving training models using human assessments can be pursued for this alternative method of evaluation as well. Still, the differences between coding and rating methods, as discussed above, necessitate that a different approach is followed.

Kahrimanis et al. (2010) have developed an innovative approach that aims at automatically rating collaboration quality in a way similar to the evaluation conducted by human raters in previous studies (Meier et al. 2007; Kahrimanis et al. 2009). The goal is that automated metrics of interaction that are calculated based on events stored in logfiles, are trained by collaboration quality ratings applied by human agents.

A prerequisite for the training of automated models of collaboration quality is that a large dataset of evaluation data is gathered from a large number of collaborative activities of similar characteristics. Therefore, numerous collaborative activities were arranged (Kahrimanis et al. 2010). Students collaborated in dyads trying to solve an elementary problem of computer algorithms using a diagrammatic representation. Collaboration took place with the use of a chat tool and a shared workspace where diagrams can be built. Students collaborated synchronously for sessions that lasted from around 60 minutes. The dataset gathered comprised 228 collaborating dyads. All instances of collaboration were evaluated by two raters using the rating scheme approach reported in Kahrimanis et al. (2009).Each collaborative session was rated for each dimension of collaboration quality defined by the rating scheme of Kahrimanis et al. (2009). Inter-rater reliability was ensured using approximately 1/3 of the whole dataset for that purpose.

After the application of the ratings, a set of automated metrics of interaction had to be defined and implemented in order to provide the technical basis on which automated estimations of ratings of collaboration quality would be based. The metrics designed and developed reshaped and augmented a metric set previously implemented based on logfile entries annotated with a typology that follows the OCAF model. Four categories of events were defined: *chat messages*, *main actions in the workspace*, *overall actions in the workspace* (including actions in the workspace of secondary importance as well, such as the movement or resizing of existent objects), and *overall events* (including all categories of events captured). Eight types of metrics were then defined, each one of them applied to each category of events: *number of* [], *rate of* [], *symmetry of* [], *alternations in* [], *rate of alternations in* [], *mean response time in* [], *median response time in* [], and *number of* [] *gaps per minute* (e.g. *number of [chat messages]*). 4 additional metrics were also added: *number of words per message*, number *of question marks*, *symmetry of text changes, number of objects altered more than X times*. So the final set consisted of 36 metrics. Metrics were kept relatively simple: since the aim of the study was that the metrics' usefulness for indicating collaboration quality would be tested empirically, it was deemed that the use of too sophisticated metrics was premature for this case.

A correlation analysis that was conducted led to encouraging results. Chat-based metrics were highly correlated with all dimensions of collaboration quality. The highest correlations were found for communicational and information processing dimensions (Kahrimanis et al. 2010). The most valuable chat-based metrics for indicating collaboration quality were the *number of chat messages*, the *alternation of chat messages* and the *mean response time in chat messages*. A notable exception was the *symmetry of chat messages* which did not correlate with any of the rating scheme's dimensions. Regarding workspace-based metrics, the most notable findings relate to *symmetry in main actions* or *overall workspace actions*, which are positive indicators of the quality of the commitment of students to the task, and the number of workspace-related actions, which is a negative indicator of collaboration quality on most of its dimensions. The latter finding indicates that too much activity in the workspace is usually related to bad coordination and redundant actions in the workspace.

Scores of correlation reported suggest that models can be developed, that are able to estimate collaboration quality based on automatic metrics of collaboration with relative success. For example, the highest correlation score reported between one metric and a dimension of collaboration quality is .427 for Kendall's $\tau$ metric of correlation and .552 for Spearman's $\rho$ metric of correlation ($p<.001$ for both cases). More importantly, correlation scores of similar level are reported for many cases, something that suggests that it is likely that models built can indicate collaboration quality with a high score. More generally, if such an approach leads to good estimation rates some practical applications would be available. Timely feedback could be given to participants targeting specific dimensions of collaboration where it is found that they have problems in a similar way to a pilot study conducted by Meier et al. (2008), but using automated means.

## 7 Conclusions

This chapter presented an overview of logfile-based interaction analysis techniques as a tool for supporting processes of Computer Supported Collaborative Learning. It included a discussion on common practices of supporting collaborative processes in ways that are deemed beneficial for the participants. A major categorization was made between interaction analysis techniques that are fully automated and based on event logs in a top-down manner in order to mirror or guide the collaborative process, and interaction analysis techniques that require the interference of human evaluators. It was claimed that while the former approaches have the practical advantage that the support of the collaborative process based on them can be timely and totally automated, they often lead to indications that are extensively based on surface representations of interaction. Similarly, the latter approaches may cover more meaningful aspects of collaboration accessible to the human intellect but they miss many of the practical advantages of automated ones. Therefore, special emphasis was then given to a recent thread of interaction analysis techniques that aim towards automated interaction analysis provided that the metrics and other technical aspects of automated calculations have been appropriately trained by deeper-level evaluations made by human agents. It is believed that the latter types of approaches are the most fruitful for reaping the benefits of the technology of collaborative tools in order to achieve automated support for the collaborative process that stands at similar levels of sophistication with other human-based evaluation approaches, rather than resorting to shallow criteria of evaluation.

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