Agent-Based Collaboration Systems: a Case Study

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Abstract

Existing distance learning systems provide collaboration tools (like forum, chat, wiki, etc.) presenting some limits that reduce the effectiveness of such tools from the standpoint of collaborative learning. Accordingly, a conceptual framework is needed that bridges the gap between the interaction forms characterising collaborative learning and existing learning collaboration tools. In this context, Multi-Agent System (MAS) seems to be a suitable paradigm to engineer such systems as it promotes effective collaboration. This paper shows how the Agents and Artefacts (A&A) meta-model for MAS could be exploited to build a conceptual framework for collaborative learning systems.

1 Introduction

Collaborative learning — where students participate in small-group activities and take responsibility for learning, whereas the teacher is more a facilitator than a "sage on the stage" (Resta et Laferrière, 2007) — leads to deeper level learning, critical thinking, shared understanding, and long term retention of the learned material than more traditional approaches (Kreijins et al., 2003). For such reason, collaborative learning and its supporting technology have collected a growing interest.

However, existing distance learning platforms often provide collaboration tools (like forum, chat, wiki, etc.) that present some limits: *i)* they are often juxtaposed and not truly integrated with one another, so collaborating people are exposed to a series of problems that come from the visually and functionally separate nature of such tools (Mühlpfordt et Stahl, 2007); *ii)* most of them provide statistical data related to on-line social interactions of students, but often they not provide an automatic analysis of such interactions. This lead to some drawbacks because teachers are subject to an added overhead if they want to make a quantitative and / or qualitative analysis of such data; *iii)* they do not share a common conceptual framework, so as to make it difficult to exploit them altogether in a coherent and effective way (Nardini et al., 2008).

As a consequence, a conceptual framework is needed that features an integrated set of tools for supporting collaborative learning and automatic analysis of student social interactions, so as to improve learning process in students and facilitate the work of teachers. In this context, *Multi-Agent System* (*MAS*) (Omicini et Poggi, 2006) represents a suitable paradigm to engineer distance learning systems promoting effective collaboration and overcoming the aforementioned limits.

Accordingly, in this paper, after we show some limits of today's collaboration environments (Section 2), we discuss how meta-models like the *Agent and Artefact* (*A&A*) (Omicini et al., 2008) — a framework that aims at directly modelling and engineering the MAS *environment* — one could exploit as a conceptual framework to design collaborative distance learning systems (Section 3). Finally, in order to prove the efficiency of the meta-model for solving the mentioned issues, we show a case study that integrates the *chat* service of the Moodle platform — a wide used platform in e-learning that is web-based and open-source (The 1st Report of Minerva-RESET Project, 2007) — with the corresponding *wiki*

service, and monitors student activities making automatically a quantitative analysis of student collaboration activities (Section 4).

2   Collaborative Learning Environments

Accordingly to (Dimitracopoulou, 2005), by focussing on *social interaction* — the key element of collaboration (Kreijins et al., 2003) — and *collaborative learning*, existing e-learning platforms — a comprehensive list of the most adopted platforms for collaborative learning can be found in (The 1st Report of Minerva-RESET Project, 2007; Online Collaborative Learning in Higher Education, 2007) — usually address this issues by providing collaboration environments that include two main necessary spaces of interaction:

- *Task space*, that is where students interact with task objects (e.g. a graphical or a textual workspace). Accordingly to (Dimitracopoulou, 2005), on the basis of the task space, two kinds of collaboration system can be identified: *i) action-oriented collaboration systems* — systems where students interact with the task objects producing knowledge. The knowledge produced represents itself a subject of discourse; *ii) text-production-oriented collaboration systems* — systems where students mainly produce a written text in a collaborative way.

- *Discourse space*, that is a mean of dialogue (Dimitracopoulou, 2005) (e.g. a chat, a forum, or a audio channel). Discourse spaces provide either an asynchronous or a synchronous communication mode. Usually, systems — either action-based or text-based — all provide one or more dialogue tools. In fact, according to (Dimitracopoulou, 2005), dialogue tools are considered crucial not only for collaboration but also for learning. In (Dimitracopoulou, 2005) Dimitracopoulou states that: *i)* "*externalization achieved through written dialogue that is conducted during collaborative activities may have significant effects, especially for conceptually rich learning activities*"; *ii)* "*interactive linguistic exchanges among people play an essential role in the elaboration and perpetuation of concepts, while the primary use and mechanism for acquisition of these concepts is the result of social interaction*".

Accordingly to (Mühlpfordt et Stahl, 2007), the activities in task space and discourse space are typically related to one another but often, this two kinds of space provided by e-learning platforms are physically and functionally dissociated (The 1st Report of Minerva-RESET Project, 2007; Mühlpfordt et Stahl, 2007; Nardini et al., 2008), so, for example, according to (Dimitracopoulou, 2005; Mühlpfordt et Stahl, 2007), it is hard for user to track and specify content and temporal relationships between the dialogue and the actions in the task space. In particular, Mühlpfordt and Stahl in (Mühlpfordt et Stahl, 2007) identify three main issues: *i) Deictic references* — the referencing of objects in the task space from the discourse space. This is an important feature that has to be provided by platforms because in virtual environments the gestural pointing is not possible; *ii) Decontextualization of action and messages* — whereas often the discourse space history represents the complete temporal sequentiality of the discursive contributions, the same does not often hold for the task space. This is another important aspect that has to be taken into account by platform developers in order to preserve the workspace context at various time instants and represent its evolutionary process making possible reflection on the whole collaborative construction. Space history is important not only for group members, but also for other groups that want to observe and exploit the built knowledge. In other words, space history can promote an effective reuse of the knowledge generated by different groups: this is viable with respect to groups belonging to different courses; *iii) The coordination of communication and interaction* — different participants can simultaneously be typing and posting message in the discourse space or

producing objects in the task space. In collaboration, these various activities are interrelated, so the awareness of the activities of the other people is a prerequisite for the construction of common ground.

Accordingly, most existing distance learning systems provide the task and discourse spaces that do not share a common conceptual framework, so as to make it difficult to exploit them altogether in a coherent and effective way in order to overcome the previous-mentioned limits (The 1st Report of Minerva-RESET Project, 2007; Nardini et al., 2008).

In addition, most of the e-learning platforms provide statistical data related to on-line social interactions of students. Often such statistical data consists in log files that collect information like student access time and the time spent by students in the e-learning system (The 1st Report of Minerva-RESET Project, 2007). As a consequence, to make a quantitative and / or qualitative analysis of such data — useful for the sake of student-interaction analysis in order to evaluate students and give them feedbacks (Dimitracopoulou, 2005; Dimitracopoulou et Komis, 2005; The 1st Report of Minerva-RESET Project, 2007; Nardini et al., 2008) — teachers often have to adapt the information provided by log files and adopt external systems to the platform. This lead to some drawbacks because teachers are subject to an added overhead.

As a consequence, a conceptual framework is needed that features an integrated set of spaces and tools for supporting and monitoring collaborative activities in an effective way.

3   The A&A Meta-model for Collaborative Environments

Distance learning lacks a conceptual framework aimed at designing integrated collaboration spaces (both task and discourse spaces) and tools for monitoring collaborative learning by an automatic analysis of student social interactions.

In this context, *Multi-Agent System* (*MAS*) (Omicini et Poggi, 2006) — a set of autonomous, pro-active, and interacting computational entities called *agents*, situated in an *environment* where they interact typically producing a coherent global system behaviour — seems to be a suitable paradigm to engineer distance learning systems. In literature, MAS paradigm has proven to be a suitable paradigm for dealing with the engineering of complex software systems like distance learning systems, which are interaction-oriented, distributed, dynamic, and open (Omicini et Poggi, 2006).

In particular, the *Agents & Artefacts* (*A&A*) meta-model (Omicini et al., 2008) seems to be a suitable framework for supporting the development of MAS-based collaboration environments.

The A&A meta-model takes inspiration from *Activity Theory* (AT), which is aimed at studying collaboration activities in human organisations (Nardi, 1996). According to AT, human activities within an organisation are always mediated by some kind of *artefacts* — either physical or cognitive tools that *enable* and *constrain* human activities. In particular, by means of the artefact abstraction provided by the A&A, a designer could design, through *function* elements, mediation instruments for human collaborative activities. Moreover, if we look at the A&A meta-model from the standpoint of *Distributed Cognition* (Kirsh, 1999) — which proposes that human knowledge and cognition are not confined to the individuals, but is instead distributed by placing memories, facts, or knowledge on the objects, individuals, and tools in our environment — each artefact can work as a repository of the knowledge built through collaborative work of human beings, which is then properly stored, organised and effectively reused. In addition, artefact properties make it possible for software agents automatically to monitor collaborative activities of human beings and perform an automatic analysis of student social interactions.

As a consequence, the A&A meta-model seems to be a natural candidate as an effective and consistent conceptual framework since it provides a set of suitable abstractions for

modelling systems supporting human collaborative activities. Accordingly, as showed in the next Section, through an appropriate design of artefacts, it is possible to frame collaboration spaces and monitoring tools as artefacts, then, by exploiting artefact properties and the agent abstraction (Omicini, 2006), integrate such re-framed tools in a conceptually uniform collaborative environment, in order to overcome the aforementioned limits.

4   A Case Study

Moodle — a wide-used, open-source, Web-based platform in e-learning (The 1st Report of Minerva-RESET Project, 2007; Ardito et al., 2004) — provides several tasks and discourse spaces that are physically and functionally dissociated. Moreover, Moodle allows to access statistical data related to on-line social interactions of students, but does not provide any tool for automatic analysis of such interactions.

In order to show the effectiveness of the A&A meta-model as a conceptual framework to design collaborative learning systems solving the aforementioned issues, we exploited the meta-model to re-frame and integrate two Moodle tools with each other: the *chat* tool — a discourse space that allows learners to communicate to each other in a synchronous way and coordinate their collaborative activities — and the *wiki* tool — a task space that encourages students to mainly produce written text or reports in a collaborative way. Moreover, we provided Moodle with an automatic analysis of student social interactions.

4.1   Moodle Design Abstractions vs. A&A Meta-model

Moodle is a Web application that does not lie on top of a conceptual framework providing the abstractions suitable to develop collaboration tools. Accordingly, it is complex to extend the functionalities provided by existing collaboration spaces. In particular, it is hard to integrate two distinct collaboration spaces from the functional and user interface standpoint—user interface is usually represented by a browser. Indeed, even though in this kind of Web-based, e-learning platforms, tools are conceived in terms of services — a set of functionalities — to be provided to platform users, the way such services are actually designed is left to designers. In particular, Moodle realizes the abstractions of service in terms of Web pages. Since a Web page is strongly related to what shown within a user's browser application, it does not seem to be a viable support to reify a service. In fact, it is difficult to concretely represent concepts that describe a service, like *service interface* — set of functionalities provided by the service — and *service behaviour* — how the service implements the provided functionalities —, by adopting a service implemented by Web pages.

On the other side, according to (Ricci et al., 2006), the A&A meta-model provides a set of abstractions allowing to explicitly model both the concept of service interface and that of service behaviour by adopting the abstraction of *artefact*. In fact, an artefact allows to model any collaboration tool in terms of *user interface* — by which an artefact can act for a specific purpose, i.e. the set of operations provided by an artefact — and *structure and behaviour* — representing how the artefact is implemented in order to provide its function (Ricci et al., 2006). Moreover, using the artefact property called *linkability* (Ricci et al., 2006) — allowing artefacts to invoke operations of other artefacts — it is possible to functionally integrate to one another the collaboration tools designed as artefacts (Nardini et al., 2008).

In addition, to realize collaborative environments able to automatically monitor social interactions arising within collaboration tools by students of a same group, it is fruitful to adopt abstractions that allow at design time to explicitly model the entities able to observe in a proactive way such interactions. On the one hand, this can be exploited in order to automatically analyze social interactions among students as a useful means to both evaluate students and give them feedback. On the other hand, it can be exploited to realize one of the necessary aspects to integrate different collaboration tools: the *awareness* on the activities

performed by each member of a collaborative group, that is crucial for communication and interaction coordination as described in Section 2.

While the Web page does not represent a viable abstraction to explicitly model the aforementioned entities, A&A provides the *agent* abstraction (Omicini et Poggi, 2006; Omicini, 2008) introduced in the Section 3. Agents are autonomous and proactive entities that can exploit some interesting artefact properties, in particular *inspectability* (Ricci et al., 2006) — the capability of observing and controlling artefact structure (state) and behaviour at runtime. Such a property can be hence exploited by an agent to monitor the interaction occurring among student of each group within an integrated collaboration.

4.2   Improving Moodle through A&A Meta-model

For the sake of simplicity, visual integration is not treated in the paper as it would require additional technologies that are out of the scope of this work and will be matter of future work. Accordingly, here we focus on a functional integration between two collaboration tools provided with Moodle: wiki and chat. In particular, integration consists of giving an user the possibility of making a reference between a chat message and the wiki content object of the chat discussion the message is part of (see Figure 1). This makes it possible to solve the problem pointed out by Stahl as *deictic references* (see Section 2), which is due to the fact that gestural pointing is not possible in virtual environments. This makes it possible to solve also the problem known as *decontextualization of action and messages* described in Section 2. Indeed, since chat messages represent the complete sequentiality of a discursive contribution, references between chat and wiki allow to make a complete sequentiality also among contributions added to the wiki.
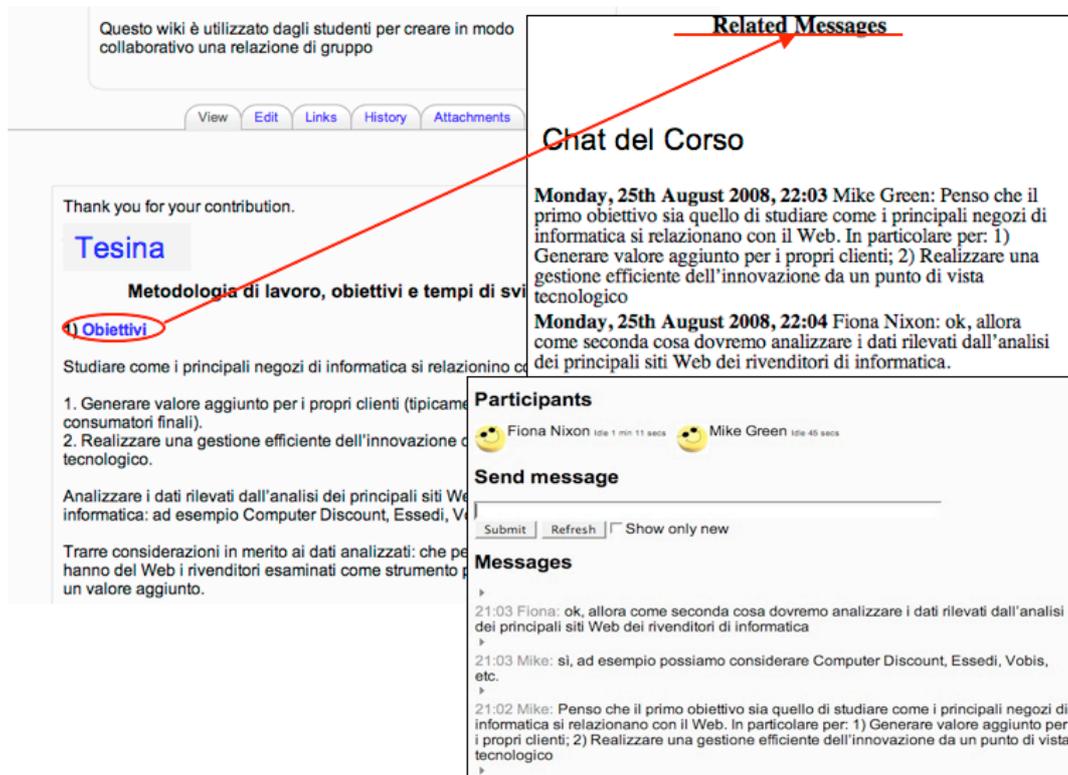

Figure 1. Relation between wiki content and one of its related discussions

To get into the details of the integration realized between chat and wiki, we defined three artefacts:

- *HttpMon*, which observes the HTTP requests coming from client browsers. In particular HTTP requests related to chat and wiki are translated in events that are sensed by the agents in charge of managing chat and wiki. To this end, *HttpMon* exploit *situation* (Ricci et al., 2006; Omicini, 2006) — i.e. the artefact property of being immersed in an external environment, and being reactive to environment events and changes so as to make it possible to intercept the requests coming from client browsers regarding chat and wiki targeted to Moodle server.

- *Chat*, which reframes the Moodle chat as an artefact managed by a *chat agent*. When such an agent perceives from *HTTPMon* an event concerning the insertion of a new chat messages or a request to create a new references targeted to a specific point of wiki content, it respectively registers the chat message and the reference into the artefact. In particular, when chat agent requests to create a new reference, the artefact exploits *linkability* (Ricci et al., 2006) with wiki artefact in order to know whether the point of wiki content to be referred exists. If such a point does not exist yet, the reference is not created. In addition, when perceiving from *HTTPMon* an event requesting to access references of a message, chat agent can exploit chat operations so as to get such references and inserts them as HTTP parameters of the request to be sent to Moodle server.

- *Wiki*, which reframes the Moodle wiki as an artefact managed by a *wiki agent*. When such an agent perceives from *HTTPMon* an event concerning the insertion of a new wiki content, a point of wiki content to be referred by a chat message, or a new reference to chat messages referring a point of wiki content, it respectively registers the wiki content, the content point to be referred and the reference into the artefact. In particular, when wiki agent requests to access references of a specific content, it can exploit wiki operations so as to get such references and inserts them results as HTTP parameters of the request to be sent to Moodle server. On the other hand, the artefact exploits *linkability* with chat artefact in order to obtain the list of all the chat messages pointing to that particular content. Linkability is also used when a content is to be deleted from wiki. In this way it is possible to delete the chat messages referring to the content to be deleted before proceeding with content deletion.

As a second aspect of this work, we focus on the analysis of social interactions occurring among the members of each student group by collaboration tools. In particular, as a reference example, we show how it is possible to automatically perform a quantitave analysis of interactions by means of *Social Network Analysis* (*SNA*) (Calvani et al., 2005). To this end, the most remarkable collaboration tool is *forum* (see Figure 2) since it makes it possible to know both the sender and receiver of a message. On the contrary the chat and wiki tool provided by Moodle do not allow to clearly know the sender and the receiver of a message; each interaction involves all group participants. As a consequence, the subsequent SNA analysis would be meaningless.
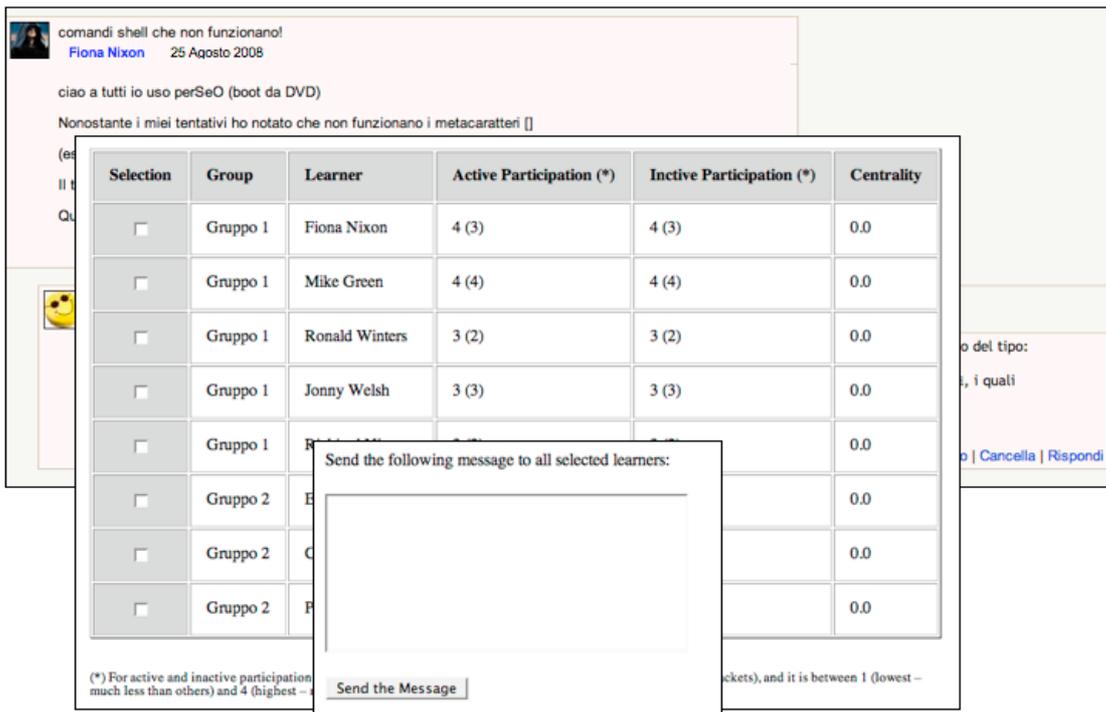
Figure 2. An automatic analysis of social interactions occurred through Moodle forum

In order to devise an automatic interaction analysis of the interaction occurred through forum, we developed the following components:

- *HttpMon*. Other than translating in events the HTTP requests related to chat and wiki, HttpMon translate the HTTP request related to forum in events that are sensed by the agent in charge of managing forum.

- A *Forum* artefact, whose goal is to reframe Moodle forum as an artefact. A *forum agent* is associated with such an artefact with the task of insert new forum message in the artefact itself.

- An *Interaction Analysis* artefact, having the goal of storing all the necessary data to actually perform interaction analysis. This artefact is as well managed by a specific agent that, when perceiving from *HTTPMon* an event requesting interaction analysis results, inserts analysis results as HTTP parameters of a request to be sent to Moodle server.

- A *Forum Analysis Agent*, whose goal is to observe the state of Forum artefact so that to insert into the Interaction Analysis artefact the data to SNA analysis on forum activities.

5   Conclusion and Future Work

In this paper we focused on some of the required features of collaboration systems in distance education. In particular we considered functional and visual integration of collaboration tools as well as automatic interaction analysis (see Section 2). As distance learning systems often provide collaborative tools not integrated with each other and not sharing a common conceptual framework, an effective and integrated exploitation of such tools becomes difficult. On the other hand, such systems allow only to access statistical data about student

social interactions, which often consists of log files. As a consequence, analyzing such a data in an automatic way becomes impossible if one does not rely on external tools.

Accordingly, in this paper we sketched a possible conceptual framework defined in terms of the *A&A* meta-model in order to allow the development of collaboration tools conceived as *artefacts* that can be easily exploited altogether in a coherent and effective way. Furthermore, A&A provides also *agent* abstraction, which can ease the monitoring of student social interactions by observing the artefact counterpart of collaboration tools.

In order to provide an example of the applicability of A&A to this scenario, we have reframed *chat* and *wiki* tools of Moodle e-learning platform in terms of artefacts. Moreover, to give an example of automatic interaction analysis, Moodle *forum* was rethought is terms of artefact and by defining a few agents, developed a prototype of *Social Network Analysis*.

How showed in Section 4, even though integration of Moodle's chat and wiki is still feasible without the adoption of artefacts, nonetheless the exploitation of artefact can make integration more scalable and efficient especially as regards dynamic scenarios. Moreover, as far as *awareness* of group members' activities (see Section 2) and *automatic analysis of social interactions* among students is concerned, Moodle technologies appear inadequate: indeed, even adopting dynamic HTML technology on the client side, server side still need to be designed in terms of proactive entities (like agents) able to observe the activities each group member is involved in (see Section 4).

Visual integration of Moodle collaboration tools was not addressed as well since it would require a complete reengineer Moodle user interface. In the end, we think that a complete redefinition of collaboration tools in terms of A&A would provide more advantages than integration of existing collaboration tools. This will be matter of future investigation.

6   Acknowledgements

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