An Intelligent Task Assignment and Personalization System for Students' Online Collaboration

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Abstract. This paper discusses a framework that supports collaborative learning activities in smart environments. When designing or developing collaborative environments numerous fundamental requirements should be taken into consideration to maximize their potentials. These best-practices outline strategies regarding (i) group formation, (ii) role assignment, (iii) personalized support, and (iv) activity monitoring. A multi-tier architecture scheme is employed, on top of the "ClassMATE" system, where every module addressees some of these aspects and their combination results in a complete framework that enables both online and offline collaboration in the smart classroom.

Keywords: ambient intelligence, education, smart classroom, collaborative learning.

1 Introduction

The evolution of Information Technology (IT) for more than three decades has drastically affected the way users interact with personal computers and increased their expectations from technology. Towards this objective, researchers developed novel concepts to provide content-rich invisible computing applications, eventually leading to the emergence of the Ambient Intelligence paradigm. Ambient Intelligence is a vision of the future which offers great opportunities to enrich everyday activities (e.g., on the road, at home, at work, etc.). Considering that ICT (Information and Communication Technologies) have been proven to play an important role in education, this work investigates the promising potentials of AmI in the education domain and in particular in the domain of collaborative learning.

The notion of Smart Classroom has been around already for a few years. In a Smart Classroom, conventional classroom activities are enhanced with the use of pervasive and mobile computing. However, the majority of the current approaches towards the realization of the Smart Classroom address various issues unilaterally, either from the technological or the educational perspective, neglecting the main objectives of disseminating knowledge and supporting the student during the learning process.

Education is defined as the process of acquiring general knowledge, developing judgmental thinking and generally preparing oneself intellectually for mature life. The

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Smart Classroom can be considered as a vehicle towards achieving these goals, as the presence of computer technology not only motivates learners' engagement in the various learning activities but also establishes the groundwork for computer-assisted collaborative learning applications that benefit from context-awareness. The work reported in this paper aims to introduce an innovative solution for efficient learning through collaboration in smart environments.

2 Background

A learning approach can be classified under one of the following classes: individualistic, competitive and collaborative. In individualistic learning, knowledge is acquired as the learner studies at his own pace towards mastering a topic. In competitive learning, a learner acquires knowledge by maximizing performance and overwhelming every opponent. Finally, in collaborative learning, a learner consciously acquires knowledge and masters a topic and unconsciously cultivates his social skills through participating in group activities. Two independent studies, [8] which dealt with traditional learning approaches without any technological aid, and [1] which examined computer supported learning, reached the conclusion that collaborative learning offers both a better learning experience and knowledge gain.

Collaborative learning is often confused with the notion of co-operative learning and used interchangeably in the literature. According to [1] co-operative work is accomplished by the division of labor among participants, where each person is responsible for a portion of the problem solving, whereas collaboration involves the mutual engagement of participants in a coordinated effort to solve the problem together. The mutual engagement in group activities unveils the social aspects of collaboration, as several social skills are cultivated in addition to cognitive skills. In conclusion, through collaborative learning, learners improve their performance [7], achieve results of high quality, shape positive attitude towards instructional experience [8], increase their metacognitive understanding and rate of knowledge capturing [12], and eventually achieve mastery.

Concurrently with the explosion of the World Wide Web, the need for remote (anywhere) and asynchronous (anytime) education revolutionized collaborative learning, while the emerging concept of computer-supported collaborative learning (CSCL) was proven to have a positive impact on students' learning [1, 5, 10, 8, 12, 14, 18, 6]. In this respect any computer – supported collaboration system should follow the features discussed next in order to maximize its potential impact:

- A collaborative task should incorporate both group and individual goals to motivate active participation and maximize the quality of the results [16].
- A group should be formed in a way that not only maximizes cohesion and density but also includes members that can be benefited the most from their participation (e.g. average learners) [5, 12, 7].
- Social skills can be cultivated through collaboration. However, extended engagement with organizational activities may result in focus loss or uneven roles distribution [17]. To address that, predefined collaboration scripts [10] can be introduced at the beginning of the task to control roles distribution and eliminate

potential collisions that may occur due to emerging, unforeseen roles. Scripts usage though should remain limited and gradually fade out, as organization skills, cooperation abilities and intergroup relations are only learned through active involvement in the planning process [2, 16, 14, 5].

- Learners' participation and knowledge inference can be maximized by [14, 16, 5, 12]: (i) enforcing continuous instructor's involvement which motivates contribution and (ii) advertising the "head" participants as collaboration centers where the less-active members can seek for unassigned or incomplete tasks.
- Finally, monitoring of the overall collaboration process can be exceptionally useful as [6, 18]: (i) collaboration patterns and "best-practices" can be identified for future reuse, (ii) personalized assistance can be provided when necessary and (iii) employment of acquainted skills can be evaluated in practice under real conditions.

3 Related Work

During the past decades the emerging field of educational applications and in particular collaborative learning applications, received much attention by the ICT community resulting in a diversity of approaches, ranging from small-scale systems aiming to motivate active participation to large-scale systems supporting every aspect of a collaborative activity.

In more detail, [13] proposed a collaborative platform where a combination of hand-writing recognition hardware and software enabled the exchange of text-based notes between the participants of a group and their instructors. In [20] situation-aware portable devices (i.e., PDAs) facilitated students' enrollment in a course (e.g., deadline reminders, personal area, etc.). In addition to course-related facilities, a limited set of desirable collaborative features was also supported like data synchronization and exchange. As regards the group formation, that task was performed offline by the instructor prior to the activity's initiation.

A similar approach is presented in [4], where interconnected handheld devices were provided to the learners to enable their interaction, whereas a monitoring strategy was applied to collect real-time data. Those data were instantly analyzed by the instructors to determine their corrective actions, which eventually assisted learners with acquiring new knowledge on their own. In [19] a ubiquitous learning environment was proposed which aimed to optimize collaboration and maximize success potentials by selecting: (i) the right collaborator, (ii) the appropriate content and (iii) the suitable service. The various collaboration actions were performed automatically (i.e., group formation, content discovery, content exchange) while every interaction was monitored by the system. Learner's profile is mostly exploited during group formation while during collaboration, its use remains limited resulting in inadequate personalized assistance.

In [3] a new system that could be easily tailored by educators in order to support the realization of scripted collaborative learning situations was presented. On the one hand it enabled instructors to provide a script that specify the sequence of activities, and on the other hand it employed grid-oriented technologies to provide the necessary activity tools to the learners. Personalized guidance was also supported to help learners while performing task activities. Finally, in [15] an agent-based system was proposed, whose core consisted of four major components that offered the necessary collaboration-related functionality (i.e., activity planning, monitoring, evaluation, assistance and administration). In terms of user interface, every "screen" was presented in the form of a web page dynamically generated by servlets and applets.

However, all the aforementioned approaches lack the dimension of environmental context – awareness that could foster collaboration among students. In this paper an innovative framework is proposed to bridge that gap and outline the benefits of computer-assisted collaborative learning in smart environments.

4 Architecture Overview

The proposed framework is built on top of the ClassMATE system [11] and adds support for collaborative educational activities. ClassMATE aims to bridge the gap between the ambient environment and the educational applications in a transparent manner, by enabling applications to exploit contextual information provided by the environment, in order to enhance the educational process. In particular, ClassMATE facilitates student's learning activities by simplifying everyday tasks and personalizing content to every individual learner. On the other hand, ClassMATE assists the teaching process by automating common teachers' activities (e.g., material distribution, homework collection, progress monitoring), thus permitting the teacher to better focus on the educational process.

ClassMATE follows a modular architecture and its core consists of four major components layered in parallel: the Device Manager, the Data Space, the User Profile and the Security Manager, glued together via the fifth major component, the Context Manager. These five major components also provide the building blocks for additional functional modules that can be developed and integrated into the system.

The Context Manager is the orchestration component of the ClassMATE's architecture. It monitors the ambient environment and makes context-aware decisions that control the operation and collaboration of ClassMATE's services and applications. The Device Manager offers a generic mechanism for heterogeneous devices manipulation by any ClassMATE-enabled application in the ClassMATE cloud.

The role of the Data Space is threefold: (i) it implements a centralized content repository, providing transparent content access and management, (ii) it encapsulates a content classification mechanism, based on IEEE's LOM specification [9], providing the necessary content-related rationale to data mining procedures, and (iii) it encapsulates a sophisticated filtering mechanism for personalized content delivery. Finally, The User Profile implements the classroom's users (students and teachers) behavior monitoring and evaluation, in order to provide user related metadata to the ClassMATE's services and applications.

4.1 The Collaboration Manager and Collaboration Strategy Manager

As aforementioned, ClassMATE offers fundamental functionality of a smart classroom enabling thus extensions to be added such as the Collaboration Manager and Collaboration Strategy Manager, which provide intelligent manipulation of collaborative activities in the classroom. The Collaboration Manager acts as a special-purposed Context Manager which handles the various collaborative activities of the classroom's users, in strong cooperation with the Collaboration Strategy Manager, upon the built-in ClassMATE's monitoring mechanism which facilitates the overall notification process. Figure 1 presents the architecture of the Collaboration Extension, described in detail in the next section.

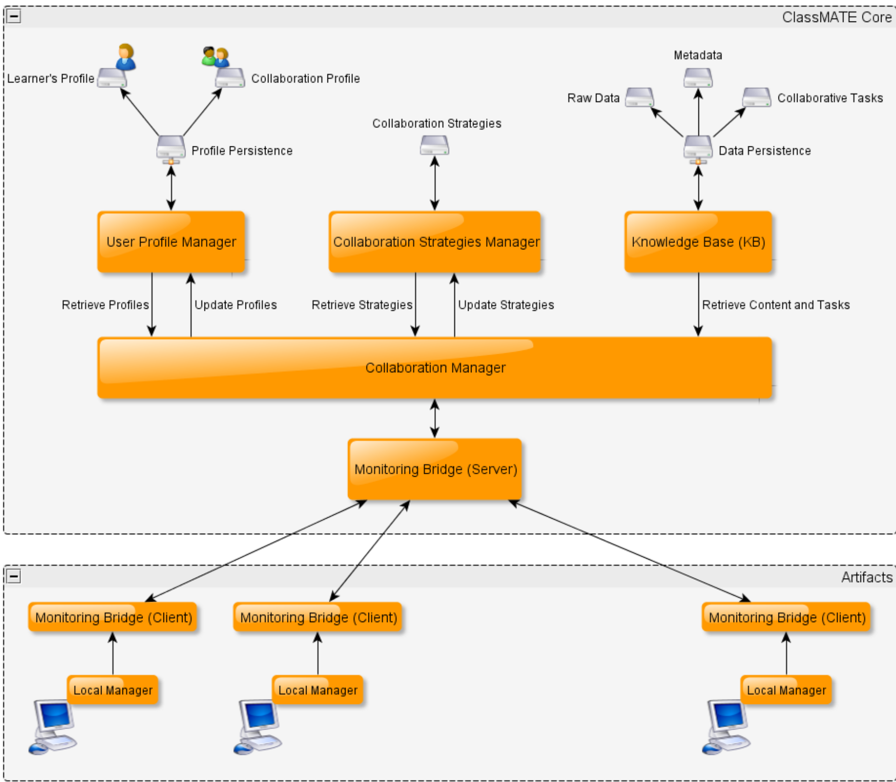

Fig. 1. Collaboration extension of ClassMATE

5 Implementation Details

Every collaborative tasks lifetime includes the following phases: (i) planning, throughout which the initial preparation of collaboration activities takes place, (ii) enactment during which the collaboration plan is deployed and monitored in real-life situations, and (iii) evaluation which aims to qualify and quantify the acquired knowledge against a short- and long- term education plan.

5.1 Collaborative Activity Planning

In the planning phase the Collaboration Manager sequentially executes the following sub-tasks: (i) identification of the task's requirements, (ii) designation of the candidate participants, and (iii) role assignment to each participant. Taking advantage of the ClassMATE platform, the entire process can be executed automatically, while the instructor can modify, at real-time, the role mappings if necessary.

In order for ClassMATE to effectively orchestrate the content delivery and provide context – aware services to the students, it handles every educational content used in the classroom as a Learning Object which is accompanied by LOM-based metadata that describe its educational attributes and facilitate its automatic retrieval. Nevertheless, LOM does not include any collaboration-related attributes, whereas the various extensions [10] proposed to address collaboration have not been standardized yet. In the presented approach a hybrid model is adopted. The LOM schema remains unchanged, the necessary collaboration concepts compile the "Collaboration Taxonomy" and every learning object can be associated with a concept through the content classification mechanism. The combination of native educational-oriented LOM attributes (e.g., part-of, difficulty level, domain, etc.) with collaboration aspects (e.g., two-person assignment, highly collaboration skills needed, etc.) can fully describe a learning object and subsequently facilitate its automated discovery in the context of a collaborative assignment.

In addition, the ClassMATE's User Profile module is able to determine the selection of the best candidate for an assignment, however it is not adequate for selecting coherent collaborative groups. Therefore, the collaborative profile was introduced to aggregate the necessary attributes that characterize the learner's behavior inside a working group and publish them to the Collaboration Manager. The included attributes are: (i) co-operability, that defines learner's ability to operate in a team, (ii) productivity, that measures learner's active involvement and contribution in group activities, (iii) rate of conflict, that reflects the learner's the spirit of contradiction, (iv) punctual behavior, which shows whether the learner delivers the assigned work on-time, (v) organizational skills, that measures learner's participation in the decision-making process towards task assignment and (vi) contribution type, that determines whether the learner is a "thinker" or a "typist".

Given that the collaborative task definition and the participants' collaborative profiles are available, the remaining task which is needed for the collaboration plan to be accomplished is the roles assignment task, which is the most challenging. Given a collaborative task *ct*, with the educational requirements *er* and the collaboration requirements *cr*, find potential participants that satisfy both *er* and *cr*.

$$\text{ct: } \{\text{er, cr}\} \rightarrow \{p_1, p_2, \ldots, p_n\}, \forall\, p_i\ \exists\, p_i \text{ attribute} \in \{\text{er} \cup \text{cr}\}$$

In order for the system to do so, initially it applies a set of semantic rules to *er* and *cr* so as to infer the quantitative attributes that a learner should have at minimum to be considered as a potential candidate, whereas both the educational and the collaboration profile are used to determine whether a learner satisfies these requirements. For example, consider the following scenario where the instructor delivers a collaborative task in which the learners should write a brief essay about Netwon's 1^{st} law. Through the inference process, the system identifies that the following criteria should be met regarding educational aspects: (i) domains: physics and foreign language, (ii) difficulty: medium, (iii) deadline: soon, and collaboration aspects: (a) number participants: 2, (b) collaboration skills: high. As a result, the system should find two participants, one with good writing skills and one good at Physics.

Additionally to the learner's profile, the system utilizes contextual information like learners' personalized schedule to exclude incompatible candidates. Finally, taking into consideration timing constraints, the system can automatically exclude candidates that are known as "trouble makers" and focus on candidates that are either punctual or have excelled in collaborative tasks in the past.

As soon as a preliminary set of candidates is defined, the instructor can either accept the suggested participants or discard them and manually define the desired groups. If manual definition is recognized to be the rule instead of the exceptional case, then the system collects the various profiles and attempts to extrapolate any patterns and associate them with the particular instructor for future use. Finally, if particular strategies are known to offer poor performance in particular cases, then the instructor can be informed beforehand.

5.2 Enactment, Monitoring and Personalized Assistance

During enactment the system initiates personalized assistance and monitoring facilities. The role of assistance is apparent, whereas the role of monitoring is twofold. From an educational perspective, monitoring facilitates progress tracking concerning either an individual, or a group or even a whole class, while from a collaboration perspective it facilitates the dynamic reconfiguration of the process's plan at run-time to handle emerging needs (e.g., participant's unavailability).

Dynamic activity reconfiguration is natively supported by the ClassMATE; however, that mechanism was extended to support dynamic reconfiguration of collaborative activities as well. The initial plan is automatically generated by the system based on the (i) assignment's predefined plan (e.g., part A should be executed before part B) and (ii) the personalized schedule of the participants. Despite that the generated plan eliminates conflicts that may occur due to activities overlap, it is still subject to modification at run-time. Certain priority rules are applied to prevent any potential deadlocks, while this feature can be disabled for particular individuals if abuse is detected.

Dynamic activity reconfiguration directly affects a learner's collaboration profile negatively or positively. If a learner constantly postpones his assigned activities then his rank will decrease. On the other hand, if a learner supplants his own schedule to facilitate the team, then his rank will increase and the system will further encourage him by planning future activities to fit his schedule.

Every collaborative activity is essentially an educational activity, thus the educational mechanisms supported by the ClassMATE system are deployed as well, and in particular the content personalization facility. The support given to a learner is adapted according to (i) his educational profile, (ii) the task's educational requirements encoded in its metadata (e.g., difficulty level, time to learn, etc.), and (iii) teammate(s) educational profile(s). The latter aims to balance contribution between "weak" and "excellent" learners, as the "excellent" will most likely surpass the “weak”. For example, if a group consists of two learners, one “weak” and one “excellent”, and they have to collaborate on a multiple choice assignment, then the “weak” learner’s participation can be encouraged by automatically enabling the extended hint option whenever a hint is asked. Similarly, if all participants need further help for the same question, then the provided hint will be personalized to their individual needs as well. For instance, in the previous example, the “excellent” learner will receive the simple and the “weak” learner the extended version of the same hint.

To ensure that learners do not take advantage of the personalized assistance facility a failsafe mechanism was introduced to eliminate any potential “ghost” users. A “ghost” user is a user who constantly asks for hints or leaves his teammate(s) to answer a question, or uses instant messaging to receive the correct answers. The system, in an attempt to discourage and eliminate such behaviors, monitors the ratio of hints requests versus individual’s contribution and the exchanged messages and upon improper use detection the strategy dynamically updates to resolve them. For instance, if a learner constantly asks for hints then system will not display the hint immediately but instead try to motivate him to answer the question by himself. As a result, the content personalization component not only records every asked hint in the learner’s educational profile to facilitate progress report generation, but also notifies the collaboration manager to update the collaboration profile if needed.

Monitoring facilitates instructors’ participation as well. First of all, computer-aided reporting simplifies class management through a multi-group view that presents the overall progress, while the instructor can focus on a particular group or even an individual participant to evaluate the progress made (e.g., actual progress, number of hints taken, correct / wrong answers ratio, etc.). Moreover, the instructor can view the created content (e.g., an essay) and motivate the participants by providing comments if necessary. Finally, a feedback mechanism is offered, through which the instructor can notify to the system about the activity’s progress and potentially modify the collaboration strategy.

5.3 Process Evaluation and Strategies’ Adaptation

The system accumulates various data at runtime and in combination with instructor’s assessment evaluates the applied strategy. During the evaluation process, both the collaboration efficacy and every individual’s progress are assessed. Based on evaluation findings the strategy will either remain the same, or the system will attempt to improve it for future use.

Collaboration strategies have been mentioned in the planning phase, where the system selects the most appropriate one for use. A strategy associates an educational task with different characteristics (e.g., assignment type, domain, difficulty level, etc.) with collaborative tasks and learners’ characteristics. The analysis of the maintained log can identify and generalize strategies that perform well in many different cases or discard those that do not. Moreover, if an ambiguity emerges where similar strategies perform equally in similar situations, then the instructor can compare them and select the most suitable. Such a decision may result in standardization of “best-practices” that maximize knowledge acquisition, and cultivation of collaborative skills (e.g., in groups of two always combine a “good” and an “average” learner to maximize the performance of both).

6 Conclusion and Future Work

This paper discussed a framework that enables collaborative learning in smart educational environments. It offers the necessary features (i.e. coherent group formation, learners' motivation, activity monitoring, etc.) to maximize its potential impact and offers a collaborative environment where the leaners can efficiently collaborate and educate themselves while the system offer personalized support to each participant.

The next steps for the presented work involve an exhaustive user-based evaluation in order to acquire additional useful feedback from end users regarding the robustness of the system, and the extension of the supported collaborative scenarios and the administration facilities to better orchestrate them.

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