AmI-RIA: Real-Time Teacher Assistance Tool for an Ambient Intelligence Classroom

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Abstract— **This paper discusses a learner-centric approach towards supporting instructors on improving the learning process in ambient educational environments. The proposed system introduces an intelligent multi-agent infrastructure that monitors unobtrusively the students' activities and notifies the teacher, in real-time, about potential learning weaknesses and pitfalls that need to be addressed. For that to be achieved several applications have been developed: (i) a real-time classroom activity visualizer, (ii) a behavioral reasoner that aims to identify common behaviors by analyzing classroom statistics records, and (iii) various mini-tools like the classroom attendance record, the schedule manager, etc. Following the system's description, findings of the preliminary expert-based evaluation are presented and future extensions are proposed.**

Keywords- ambient intelligence; education; smart classroom; teacher assistance; student monitoring.

I. INTRODUCTION

Ambient intelligence (AmI) is an emerging technological paradigm that defines sensitive digital environments that monitor their surroundings through pervasive sensorial networks and automatically adapt (i.e., AI) to facilitate daily activities [1], [2]. AmI initially benefited mainstream areas such as home and office automation. During the past few years remarkable efforts have been made towards applying AmI in a variety of domains such as education, health, etc.

In a "Smart Classroom", typical classroom activities are enhanced with the use of pervasive and mobile computing, artificial intelligence, multimedia content and agent-based software [3]. Traditional artifacts like the desks and whiteboards are replaced by technologically enhanced equivalents aiming to support the educational process. The most prevalent realizations of the Smart Classroom paradigm include applications for automatic adaptation of the classroom environment according to the context of use [4], automatic capturing of lectures and teacher's notes [5], enhancement of the learner's access to information and personalization of the classroom's material [6] and finally, supporting collaboration among the participants in the classroom [7]. However, the majority of current research approaches address issues focusing on the learner's activities, without much attention to the role of the teacher. Among others, teacher's duties include: (i) implementation of a designated curriculum, (ii) maintenance of lesson plans, (iii) assignment of tasks and homework, (iv) monitoring of performance, and most importantly (v) assistance provision when necessary. In general, curriculum activities outweigh monitoring and assistance tasks, especially in crowded classrooms, thus an automated method of observing students' behavior and identifying common problems is needed to enable effective and personalized tutoring [8].

Towards this end, a tool named AmI-RIA has been implemented, targeted to support the teacher in the context of a learner-centric ambient intelligence classroom. The AmI-RIA system monitors and analyzes students' activities in real-time so as to identify potential difficulties, either at a personal or at a classroom level, and notify the teacher accordingly (e.g., through the teacher's frontend application). The teacher can therefore concentrate on the lecture and rely on the system to monitor the classroom and prompt for an intervention only when necessary (e.g., a student is out of task or performed poorly in a quiz). In addition to real-time monitoring, AmI-RIA offers a performance analysis tool that provides extensive metrics of students' progress (based on previously collected data) that the teacher can use to identify topics that require further studying or even adaptation of the teaching methodology. Finally, AmI-RIA integrates tools that automate common procedures like attendance record keeping, quiz assessment and preparation of lesson's curriculum.

The rest of the paper is structured as follows: Section 2 presents related work on student monitoring in real classrooms or e-learning environments, Section 3 provides a description of the AmI-RIA system design, Sections 4 and 5 present system implementation details, Section 6 reports the evaluation results, and finally Section 7 summarizes the described work and highlights potential future enhancements.

II. RELATED WORK

The widespread use of ICT in learning environments has urged researchers to take advantage of the presence of technological equipment inside classrooms in order to enhance the learning and teaching process. Towards this objective, various intelligent systems that monitor students' activities and report valuable insights to the teacher have

been developed, aiming to enhance either real or virtual (i.e., e-learning environments) classrooms.

A. Student monitoring in real classrooms

Retina [9] aims to assist instructors that offer computer science courses to improve their curriculum by reporting the difficulties that students are facing during programming. To that aim, Retina collects information about students' programming activities (e.g., compilation and run-time errors, time spent for each assignment, etc.) and generates informative reports for students (i.e., self-evaluation) and instructors, whereas live monitoring enables instructors to either address issues immediately during a lecture or adjust forthcoming assignments. In [10] a system that aims to improve programming courses is presented. It monitors students' behavior within a learning environment on introductory programming (e.g., compilation errors, error messages, source code, etc.) in order to detect students' frustration -a potential factor for disengagement- and notify instructors to intervene providing help.

In [11] it is argued that teachers working in robotic classes have problems in keeping track of students' activities. As they claim, the real challenge for the instructors is to know when and how to intervene. Thus, they propose a system that collects data from the robotic environment and inform the teacher about what students are doing and how they are progressing. The design of the system relies on the LeJOS programming platform for Lego Mindstorms, where two agent modules are used for the data collection, one embodied into the robot and the other deployed on the programming environment.

MiGen [12] is a related intelligent environment designed to support students learning algebraic generalisations. The system aims to assist the teaching process by informing teachers of students' progress, the appearance of misconceptions and disengaged students. To do so, MiGen visualizes the students' progress based on their attainment of specific landmarks as they are working on mathematics generalisation tasks.

The aforementioned systems can partially provide real-time information to the instructor, however they have two major drawbacks: (i) they are targeted to specific contexts of use (e.g., programming course) and (ii) they offer rather poor user interfaces, in terms of usability, that hinder information extraction.

B. Student monitoring in e-learning environments

Similarly, various approaches exist that support instructors within e-learning environments through student monitoring. In [13] a web-based environment is proposed, capable of collecting students' traces during interaction in order to visualize the virtual classroom and help teachers keep classroom control. Participants are represented by Chernoff faces, whose facial characteristics evolve over time according to their activities.

In [14] the CourseVis tool is presented, which generates graphical representations of what is happening in the classroom (i.e., social, cognitive and behavioral aspects of

the learners) by analyzing students' activities data collected in a course management system (CMS).

Likewise, [15] is an intelligent agent system that supports teachers in supervising learners in LAMS (Learning Activity Management System). It is capable of notifying the instructor for common problems about participation and contribution of students during their activities. However, for that to be achieved, the instructor is required to determine expectations for the attendance and contribution of the learners for each activity (e.g., typical execution time, contribution level on collaborative activities, expected score, etc.). Finally, a notification agent is used to deliver messages and information to the supervisor of the lesson and to the learners as well.

The systems discussed above either lack intuitive user-interfaces (i.e., Chernoff faces are a useful tool for indicating student inactivity, but in complex situations their expressiveness is limited) or they do not offer an effective real-time assessment method needed in such intelligent learning environments [16]. Thus, there is a clear need for a system that can: (i) be deployed in a real classroom, (ii) monitor unobtrusively the students, (iii) produce valuable insights about their behavior in real-time, and (iv) deliver them through an intuitive, yet rich, user interface to the teacher.

III. SYSTEM DESIGN

The teacher assistance tool proposed in this paper aims to inform the teacher about students' activities and identify potential weaknesses by monitoring interaction and generating classroom-wide performance metrics. For that to be achieved, a distributed architecture (Figure 1) is introduced that consists of two major components: (i) an intelligent agent deployed on the students' desks to monitor interaction named *Desk Monitor*, and (ii) an intuitive frontend application deployed at the teacher's desk named the *Teacher Assistant,* that facilitates monitoring overview and simplifies classroom control (e.g., assignment submission, exam distribution, etc.).
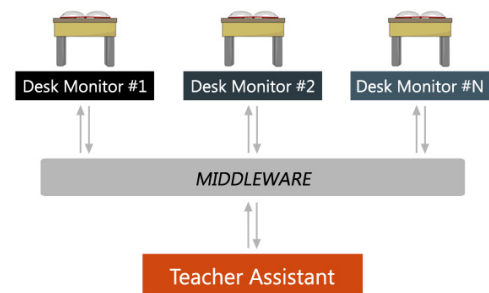

Figure 1. AmI-RIA overall architecture

Every Desk Monitor agent collects the monitoring traces that students generate when working on their desks and through a reasoning process draws conclusions about students' behavior. Both the collected and the inferred knowledge is transmitted in real-time to the *Teacher Assistant* application, which is responsible to present them appropriately (e.g., highlight inactive students, prompt

teacher action, etc.). Data exchange is performed through a generic services interoperability platform, named FAMINE (FORTH's AMI Network Environment).

A. Data Collection

The proposed system is employed in a Smart Classroom [3] and is supported by the classroom's backbone infrastructure named ClassMATE [17]. ClassMATE monitors the classroom environment and orchestrates its various artifacts (e.g., augmented school desks [18], interactive whiteboards, etc.). The augmented desk is an enhanced school desk, which uses computer vision technology in order to recognize books and book pages and provide physical and unobtrusive interaction without requiring any special device. The ClassMATE infrastructure in collaboration with the PUPIL framework [19] controls the augmented desks and the whiteboard (e.g., SMARTboard) and provides the required facilities to monitor the students' interactions during the learning sessions.

The activities of interest for the AmI-RIA system include: (i) login when a student sits on a desk, (ii) course book page fanning, (iii) launch of an exercise session, (iv) answer submission, (v) use of contextual help provided by the learning system and finally, (vi) browsing and sharing of multimedia galleries. These activities along with related data become available to the *Desk Monitor* agent by ClassMATE through a FaMINE-enabled bridge interface.

B. Data Management and Reasoning

Ontologies are widely accepted as a tool for modeling contextual information about pervasive applications [20], as they not only address the problem of data heterogeneity between applications and support data interconnection using external vocabularies, such as FOAF and Dublin Core metadata, but also enable knowledge inference using semantic reasoners whose rules are implemented by means of ontologies.

AmI-RIA aims to exploit those features thus it makes extensive use of ontologies. An RDFS schema has been implemented that defines classes for the relevant entities (e.g., Teacher, Student, Book) and the activities (e.g., Open book, Start exercise) that can potentially take place in a classroom environment, while a set of taxonomies has been defined, based on RDFS properties, to associate classes and create activity hierarchies (e.g., Submit_Exercise isA Student_Act). Collected data are stored internally in the form of RDF triplet statements.

The reasoning process of the AmI-RIA system is supported by the SemWeb library for .NET. SemWeb supports SPARQL queries for information retrieval over the data and incorporates the Euler engine, a popular backward chaining inference engine. The rules used by the Euler engine are written in external files using the Notation3 syntax, an RDF syntax designed to be human friendly. Rule decoupling facilitates system maintenance and scalability as insertion of new rules or modification of existing rules can be done without affecting the core of the AmI-RIA system.

IV. DESK MONITOR AGENTS

The Desk Monitor agents constitute the core components of the AmI-RIA system, as they execute the inference rules over the collected interaction data to identify potential troublesome situations (e.g., inactive or off-task students, etc.). To that end, the agents make use of the developed taxonomies that describe such situations and through a goal-driven method (i.e., backward chaining inference) try to confirm their existence based on contextual knowledge. The list of currently detected situations include: (i) off-task students, (ii) inactive students, (iii) students that face difficulties during exercise solving, (iv) students that face difficulties during exercise submission and (v) students that misuse the contextual-help of the learning system.

A. Off-task

According to Caroll's Time-On-Task hypothesis [21], the longer students engage with the learning material, the more opportunities they have to learn. Therefore, if students spend a greater fraction of their time engaged in behaviors where learning is not the primary goal, they will spend less time on-task and as a result learn less. In [22] the authors argue that off-task behavior indeed has a negative impact on students' performance. To identify off-task students, the system checks the material displayed on a student's desk (e.g., the currently opened book, the opened pages, etc.) to determine if it is relevant to the topic discussed in the classroom based on the activity in hand.

B. Inactivity

During classroom activities, especially exercise solving, it is common for students to start working on an exercise and after a while give up because they get bored or distracted. Inactivity is defined as a type of off-task behavior where the student does not interact with the learning object at hand. According to [22], inactivity indicates that a student is disengaged with a certain task and can be used as a quite accurate performance predictor. AmI-RIA exploits the typical learning time describing the amount of time that a student is expected to work with or through a learning object [23], to specify if and when a student's interaction is taking too long to be executed. For that to be achieved, AmI-RIA gets notified by ClassMATE about the actions that a student performed when interacting with a learning object (e.g., an exercise, a text passage, etc.).

C. Problems during an Exercise

The PUPIL framework offers personalized tutoring in the form of contextual help (i.e., hints) for each question of an exercise to help students find the right answer, where the last hint provides the maximum amount of help that can be provided. AmI-RIA monitors the amount of help asked and the selection made afterwards to calculate student's performance. In case a student uses the maximum amount of help, but still does not answer correctly, then the system infers that the student has difficulties regarding this question and the concept it refers to.

D. Problems on Exercise Completion

Identifying whether a student faces difficulties during exercise solving is quite challenging, since a single pass/fail indicator does not always reveal the actual progress of a learner on a specific topic. To this end, instead of generalizing conclusions based merely on the score of the exercise in hand, the student's previous performance on relevant topics/similar exercises is taken into consideration. Thus, detecting sparse declines of a learner's statistics does not necessarily indicate a weak student.

E. Misusing the Learning System

Sometimes students interact with exercises according to a set of non-learning-oriented strategies described in [22] known as "gaming the system". Such strategies involve behaviors aimed at systematically misuse the help provided by the system in order to advance in exercise instead of actually making use of the material of the intermediate hints. A set of rules has been created to track students who repeatedly ask for help within a small time frame until they get the maximum one.

Figure 2. The Teacher Assistant User Interface

V. TEACHER ASSISTANT

As aforementioned, AmI-RIA offers an intuitive frontend application (Figure 2) deployed at the teacher's computer (or portable tablet device) named *Teacher Assistant*, through which the instructor can monitor at real-time via live feed the activities that take place in the classroom and identify occurring issues. For that to be achieved, every Desk Monitor Agent propagates its inferences through the classroom's middleware to the Teacher Assistant application to present them accordingly.

In terms of design, Teacher Assistant adheres to the natural mapping rule [24] that leads to immediate understanding because it takes advantage of physical analogies. As such, each student present in the classroom is represented by a *Student Card*, non-occupied desks are represented by semi-transparent empty cards, whereas the layout resembles the layout of the physical desks. As a result, the teacher can easily locate a student in the classroom through the virtual class map or access the attendance record to see the absent students.

A. The Student Card

The Student Card contains both personal information, such as the name and the profile picture, and information regarding the current activities and status of the student. During the course the student might be engaged with various activities such as reading a passage from a book, solving an exercise, browsing a multimedia gallery, etc. Providing specific details on such classroom tasks would allow the teacher to be constantly informed about the students' attention levels and potential learning difficulties. To this end, each Student Card adjusts to represent the learner's status at any given moment. For instance, when a student is reading, the card displays the book title and the respective page numbers; during an exercise, additional information is displayed regarding the topic, difficulty and the student's progress, finally when a student launches a multimedia gallery, a small set of relevant keywords is displayed on the card.

However, during a lecture the students might lose interest and deviate from the teacher's suggestions. This kind of information could ideally prompt the teacher to investigate the reasons of such attention lapses and try to maintain the student's interest. For that purpose, the Student Cards are enriched with visual cues (e.g., different border color of the cards, intuitive icons) to mark on-task, off-task and inactive behaviors. Finally, since the implemented system targets large and crowded classrooms, the visual information may become too large to be handled easily. To overcome this difficulty, a filtering mechanism that allows the teacher to focus on specific student groups is incorporated.

B. Assesment

Exercises are considered to be a key aspect of the learning process in a classroom as through performance monitoring potential learning gaps can be revealed and the domains where the teacher should focus on are highlighted. AmI-RIA ensures that the teacher will be able to watch students' progress during exercise sessions by adjusting the student card appropriately to display the exercise's name, the related topic and the student's current score, whereas more detailed information about student's performance is available through two special-purposed windows.

The first one presents in more detail aspects of the exercise at hand; in particular, (i) the type (e.g., multiple choice quiz, fill-in the gap, etc.), (ii) the difficulty level (e.g., easy, medium, hard), and (iii) the typical learning time as defined in the LOM metadata. The second window (Figure 3) presents a complete log of student's actions regarding that exercise: (i) the number of answers given, (ii) the number of hints used per question, (iii) the current score, (iv) the ratio of correct and wrong answers, and optionally (v) a problem indicator as generated by the Desk Monitor.

Figure 3. The exercise progress window

In addition to exercises, tests are also integral part of the learning process. Tests are a type of exercise where every student is obliged to answer and no help is provided. As soon as a test is initiated from the Teacher Assistant application, it automatically launches on every desk while the use of any other application [19] is prohibited (e.g., Thesaurus, Multimedia, etc.). During tests, the teacher can monitor students' progress as with common exercises and is able to request its submission at any time. At that point, any tests that have not been submitted yet are automatically collected and a summarizing report is presented with an average score for the entire classroom and a precise score for each student.

C. The Classroom Monitor

Individual statistics are automatically generated for each student by the respective Desk Monitor agent; however, accumulated statistics for the entire classroom are invaluable tools for teachers as through them behavioral patterns can be identified; an activity is considered to be a pattern if it is observed in a certain number of students in the classroom. For instance, if 85% of the students faced difficulties and performed poorly in an exercise, then either that particular exercise is too difficult or the teacher has to adapt the class' schedule to further elaborate on the related concepts. Similarly, if more that 80% of the students are off-task at the same time, then either a break might be helpful or the teacher should attract their attention and enhance their motivation. In any case, when AmI-RIA identifies a pattern, a special alert is generated to notify the teacher.

D. Statistics

The information gathered about the students' activities is used to build a rich history record, which combined with the defined RDFS schema constitutes a vast source of semantic information. This information is exploited to generate statistics for the progress and performance of the students during short or long periods of time. Based on these statistics the teacher detects the topics that need to be revisited or adapted and identifies the thematic areas that seemed to have troubled each student.

The statistics component offers two alternative views, one for the classroom and another one for individuals (Figure 4). Both provide information about performance, topics with the highest/lowest scores and rankings on

students and lessons. The generated statistics can be printed and handed-out to parents as an unofficial progress report for students.
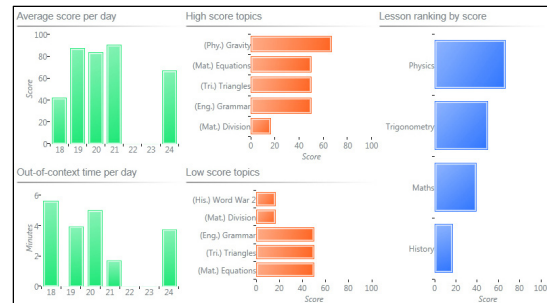

Figure 4. The individual statistics component

VI.   EVALUATION

As a first step towards the evaluation of the system, an expert-based heuristic evaluation was conducted in order to identify usability errors. The heuristic evaluation requires a small set of evaluators (3-5) to examine the interface and judge its compliance with a set of recognized usability principles. An observer notes down the issues and creates an aggregated list which is delivered at the end to the evaluators in order to provide severity ratings on each issue.

Four evaluators took part in the evaluation of Ami-RIA and identified 22 usability problems, out of which 11 were marked as severe (rated above 2.5 on a 0-4 scale). The identified usability errors were related mostly to the flexibility in access to the several components (e.g., the attendance access button) and the perceived user friendliness when operated on touch-enabled devices (e.g., the sidebar option buttons were difficult to press due to their size). Additionally, some issues were identified regarding the aesthetic design and accessibility of the user-interface such as the insufficient color contrast between the main visual components (e.g., the main menu buttons and the footer's information). The released prototype of AmI-RIA effectively addresses all the identified errors.

VII.   CONCLUSIONS AND FUTURE WORK

This paper presents AmI-RIA, a real-time system that aims to assist teachers in the context of an intelligent classroom by exploiting the available ambient technology from their perspective. The proposed system monitors the students' activities in an unobtrusive way and generates valuable insights in order to assist teachers keep track of the classroom's performance. Thereby, the teacher is supplied with the needed information to decide when and how to provide help or adapt the teaching strategy. For that to be achieved a statistics component performs queries across the entire history record and retrieves information regarding the students' progress and performance. Furthermore, a set of tools have been developed and deployed on the teacher's desk, targeted to enhance typical procedures that can be found in conventional classrooms (e.g. class attendance record, tasks assignment, etc.).

The next step of this work will be to conduct a full-scale user-based evaluation in a real classroom. The evaluation is planned to include 20 different teachers and their students [25], where typical classroom activities will be observed to: (i) assess whether AmI-RIA recognizes problems successfully, and (ii) determine how instructors use the system to identify problems and provide assistance. The evaluation's findings are foreseen to extend the currently implemented rule set and improve the user interface of the teacher's frontend application in terms of usability.

Additionally, some relevant topics are being investigated for future upgrades. A great addition to the system would be to make the students' desks aware about the inferences produced during the reasoning process. This way, the students will be informed about their performance during the various learning activities and will feel more comfortable with the monitoring process. The feedback provided could be used by the students to adjust their activities accordingly, while communication between the teacher and the students could be also enhanced with an application that blends seamlessly with student activities application. For example, the teacher using the application could reward some students for achieving great scores on a task or provide extra material to those who had problems in a topic. Finally, an important extension to the system would be the development of a graphical tool that will facilitate the intuitive modification of the rules used to identify students' states or create new ones.

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