A Glimpse into the Ambient Classroom

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***Abstract*— Ambient Intelligence is an emerging field of research that has to potential to enrich educational environments. This paper discusses a line of research targeted to investigate and introduce innovative solutions for efficient learning in smart environments through integrating AmI technology in the learning process. The overall concept of the Student-Centric "Ambient" Classroom and the related hardware and software components are described.**

***Index Terms*—Ambient Intelligence, Educational technology, Computer applications, Human Computer Interaction.**

I. Introduction

AMBIENT Intelligence (AmI) is an emerging field of research and development that has the potential to enrich educational environments and enhance the notion of "Learning with the use of ICT". It can play an important role in education by increasing students' access to information, enriching the learning environment, allowing students' active learning and collaboration and enhancing their motivation to learn [6].

The AmI Classroom activity of ICS-FORTH investigates the role of Ambient Intelligence technologies in the educational context and in the classroom environment and provides intuitive and seamless tools to improve the learning and classroom experience, adopting a learner-centered approach that involves small groups of young learners throughout the entire development lifecycle of the various activities.

'AmI classroom' is used as an umbrella term meaning that classroom activities are enhanced with the use of pervasive and mobile computing, sensor networks, artificial intelligence, robotics, multimedia computing, middleware and agent-based software [4], [5]. In this context a set of "intelligent" facilities is developed to enhance the educational process by seamlessly integrating the physical and the virtual world both inside and outside of the classroom.

The hardware infrastructure includes both commercial and custom-made components that address the space and layout limitations of such challenging environments, and introduce innovative interaction methods that extend beyond the current desktop and menu driven paradigms [15]. The software infrastructure exploits the hardware layer to monitor the classroom environment and augment the learning process to benefit the learners. The AmI Classroom features sophisticated context-aware mechanisms that monitor and assess students behavior, provide user related data to the classroom's services and applications, assist the teacher to adjust the learning activities, deliver personalized content that addresses individual student's learning needs and promote collaboration. In the next sections the developed artifacts, setups and application frameworks are presented.

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II. The "Augmented School Desk"

In the context of AmI, the classroom is a challenging environment. In practice, there are severe space and layout limits to the introduction of AmI equipment, which should be unobtrusive, hidden or embedded in traditional classroom equipment and furniture. It is very important that such equipment can be installed smoothly and easily moved around in the environment, and that space requirements are as limited as possible. This implies several constraints on how the AmI classroom environment can be developed. To address this issue, the Ambient Classroom project has adopted an artifact-oriented approach, by stepwise introducing independent AmI augmented artifacts in the environment.

The first such artifact is the augmented school desk (Fig. 1), where an additional piece of furniture has been designed to fit typical school desks of standard dimensions according to EU normative[1]. Such an 'add-on' provides a custom plexiglass 27 inches diagonal wide screen whose inclination can range from 30^{o} (with respect to desk surface) to completely horizontal. It embeds almost invisibly all the devices required for the operation of the AmI applications, and has a width of 40 cm, thus requiring relatively limited additional space with respect to the standard desk.

An important consideration in the design of the augmented school desk was that AmI in the classroom should be compatible with the school of today, as the anticipated transition to the paperless classroom did not appear so imminent. Therefore, as a first step, the augmented school desk and its educational applications smoothly integrates ambient interaction as well as digital augmentation of physical paper (e.g., [14]) by supporting paper-based learning materials and the use of handwriting. For that to be achieved, the desk

[1] EN 1729-2:2006 Furniture. Chairs and tables for educational institutions. Safety requirements and test methods.

integrates on its front side a camera that captures images of the conventional desk and a smart pen, while behind the screen two cameras implement a vision-based back projection multi-touch that avoids ceiling mounted or hanging projectors and cameras and ensures gesture interaction quality under variable lighting conditions.

Fig. 1: 3D model and materialization of the Augmented school desk

III. II. The "Ambient" Software

The software architecture of the "ambient" Classroom follows a stack-based model where the first layer, namely the middleware infrastructure, serves the interoperability needs of the classroom. The next two layers, namely the ClassMATE and the PUPIL frameworks, expose the core libraries and finally the remaining layer contains the educational applications.

The ClassMATE [11] framework is an integrated architecture for pervasive computing environments that monitors the ambient environment and makes context-aware decisions in order to assist the student in conducting learning activities, and the teacher with administrative issues (Fig. 2). ClassMATE features a sophisticated, unobtrusive, profiling mechanism that facilitates the classroom's students behavior monitoring and assessment, in order to provide user related data to the classroom's services and applications.

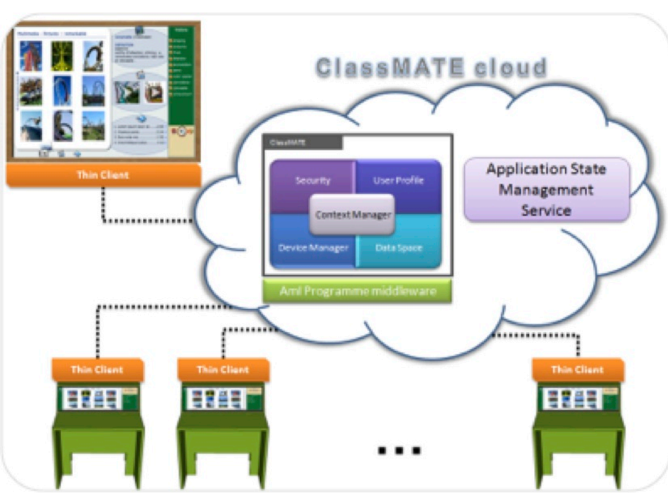

Fig. 2: ClassMATE pervasive computing and collaborative application infrastructure

The learners' record repository keeps track of every individual student's learning status by combining runtime information captured during interaction with semantic information coming from the context of use (e.g., a particular learning object) and produces statistics for the teacher that can potentially drive adjustments to the learning procedure. Besides monitoring, user profile is extensively used by the educational content classification and archiving mechanism to achieve personalized content delivery that addresses individual student's learning needs. Finally, taking into consideration that collaborative learning offers both a better learning experience and knowledge gain [7], ClassMATE simplifies the orchestration of such activities.

The PUPIL framework [9] facilitates the design, development and deployment of pervasive educational applications. Within ambient environments, and in particular inside the "intelligent classroom", user interfaces expand way beyond their static nature and become dynamic components able to react to contextual changes. In such environments every application can be launched, manipulated and migrated at any intelligent artifact.

PUPIL equips designers with a GUI toolkit targeted to support the development of user interfaces for smart classroom applications (Fig. 3). Each of the widgets contained in the toolkit can be appropriately adapted to achieve optimal display on various classroom artifacts maintaining their usability. The collection of widgets incorporates both common basic widgets (e.g., buttons, images) and mini interfaces frequently used by in educational applications (e.g., bookViewer), as ready-to-use modules. The designer can either (i) combine and customize widgets from both categories to build an interface just once, or (ii) build and incorporate it as a custom-made mini interface in the collection for future reuse.

PUPIL additionally introduces a collection of workspaces (namely Classroom Window Managers [10]) tailored to each artifacts' characteristics, that aims to deliver a sophisticated environment for educational applications hosting. A common look and feel is instantiated across the various classroom artifacts, thus transforming the classroom into a unified environment rather than a group of isolated units.

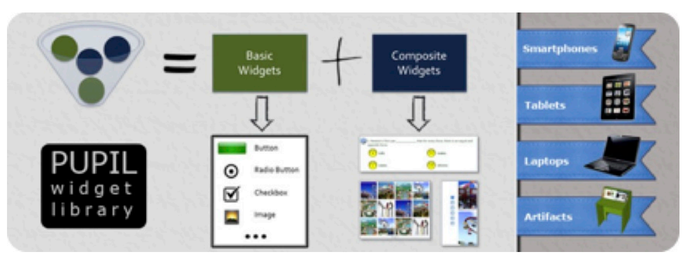

Fig. 3: PUPIL framework offers a widget library that incorporates common basic widgets and mini-interfaces frequently used for educational applications

The software applications for enhancing learning experience through the augmented desk build using the aforementioned frameworks currently include: (i) an individual personal area summarizing the current delivery status of all assignments, (ii) a dashboard for temporal storage, (iii) an exercise viewer that offers contextual help, (iv) a dictionary-thesaurus application, (v) a note-taking application, (vi) an application for viewing course related multimedia, and

(vii) language-learning games.

IV. SESIL

The SESIL system [12] introduces an augmented reality environment that provides seamless, context-aware support to students by unobtrusive monitoring their natural reading and writing process. This environment does not require any special writing device in order to monitor the student's gestures and handwriting, as it is able to perceive interaction with actual books and pens / pencils (Fig. 4).

Fig. 4: SESIL system in action

Through OCR techniques, the system recognizes words pointed by a student on a physical book and provides additional context-aware help in a near-to-the-student display. SESIL can thus enhance the learning process by unobtrusively and naturally providing additional information related to the current student's activity.

For example, it can be used in the context of learning a foreign language, or while learning one's mother language as a young student as the software provides:

1) Word preview, including up to three definitions for the given word, five representative images and five related videos
2) Dictionary data, including all the definitions available for the word, as well as synonyms and examples for each definition
3) Related to the specified word images and videos
4) Visited words history

V. AmI Playfield

AmI Playfield [13] is an Ambient Intelligent (AmI) environment for learning which offers an innovative approach, emphasizing the use of relatively low-cost kinesthetic and collaborative technology in a natural playful learning context, while also embodying performance measurement techniques.

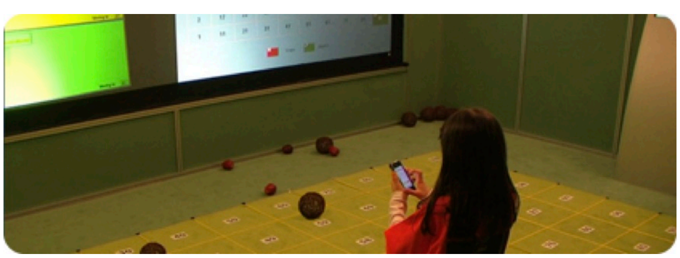

Fig. 5: Using the Math Controller to target a position

AmI Playfield is composed of the following modalities:

1) A vision-augmented playfield, capable of tracking the players' moves;
2) Various graphical user interfaces that illustrate game action dynamically from different views on a dual back-projection display;
3) A game manager used as a general remote controller, handled by a touch-screen;
4) A couple of controller interfaces, accessed through mobile phones
5) Sound facilities

A math game has been designed to help young students learn the four fundamental mathematical operations, using numbers from 1 to 100. The playfield consists of a carpet displaying 100 squares, some of which have an apple. Children are separated in two groups: the first group aims to collect as many apples as possible and the second one aims to catch their opponents. Children can move between squares by correctly calculating the mathematical operations (Fig. 5).

Output is provided multimodally with visual information displayed on a large screen for the whole class to view, and auditory feedback available for each player individually. Students' activities are monitored in order to provide appropriate personalized feedback, guidance and useful statistics. Currently, new kinesthetic games are being designed and implemented on the playfield infrastructure, including a multimodal memory game.

VI. The "Educational Tabletop Mini-Games"

The "Educational tabletop mini-games" [8] combine learning, entertainment and ambient intelligence to enhance the learning experience [1], [2], [3] and motivate learners through modern technology-enabled applications. Two games have been developed: (i) a multiple choice quiz game, and (ii) the "Place the landmark" geography-related game. Both games use physical cards as the primary interaction source. The computer orchestrates the game by monitoring the surface of a table for cards through a simple webcam and searching for potential matches.

When a known card is thrown on the table, an image recognition algorithm [12] finds the appropriate match. Subsequently, the game extracts, interprets and executes the corresponding command (e.g., select the answer of that card, place a virtual pin that represents the selected landmark on the digital map at the same location).

The "Multiple choice Quiz", as its name indicates, is a regular multiple-choice game in which players are asked to select the best possible answer out of the choices from a list. Instead of selecting an answer or a category using a traditional input device (e.g., mouse, keyboard, touch screen, etc.), players perform the same actions (e.g., selecting an answer or picking a category of questions) by throwing a physical paper card on the table; three different types of cards are contained in the deck: (i) cards that represent quiz categories and are used only for quiz selection, (ii) cards that represent answers and display the corresponding symbol (e.g., A, B, C, D), which can be used only during an active game session, and finally (iii) special-purpose cards (e.g., hints, back to menu, etc.) that can be used at any time.

Fig. 6: The “Place the landmark” customized for the island of Crete, Greece

“Place the landmark” was developed as a game that students could use to sharpen their geography skills (Fig. 6). This game engages students in a collaborative activity where they learn through experience and will retain that knowledge for longer. The player’s objective is to identify and correctly place a number of landmarks at their right location on a map. For that to be achieved, the player has a deck of cards at his disposal, where each one represents a landmark (e.g., monument, sight, town etc.), and should be placed on the physical map mounted on the table.

When the player picks a card and places it on the physical map, a virtual pin that represents the selected landmark is placed on the digital map at the same location. While the player moves the card trying to spot its correct location on the map, the virtual pin trails its movement on the virtual map. As soon as the player places the card over the correct location, the virtual pin is fixed at that point, and visual cues notify the player about his right choice. The game provides two alternative types of assistance to the players. When a player throws a card on the map or selects a landmark, related content (e.g., multimedia and text) about that landmark is presented, while the player is able to browse through the provided information and explore the studied area in a more interactive and content rich way. On the other hand, if a player delays to identify the correct location of a landmark or keeps searching in the wrong direction, the appropriate part of the virtual map is highlighted indicating the whereabouts of the landmark.

VII. CONCLUSION

This paper briefly summarizes part of the work conducted for the AmI classroom environment in the context of the ICS-FORTH AmI Programme. Overall, the results of the conducted studies are very positive and confirm that AmI technologies have the potential to enhance the classroom learning experience. Ongoing work aims to fully support the initial concept. Applications targeted to the teacher are currently under elaboration, while mobile devices are considered to be excellent candidates for incorporation in the classroom. Finally, following full implementation, a full scale evaluation experiment is being planned, aiming not only to assess the usability of the proposed environment, but its actual impact in the educational process as well.

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