A Novel Multi-Platform Service-based Approach for Learning Environments

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Abstract— Learning processes and learning mechanisms are constantly evolving. The traditional classroom boards are replaced by Internet technologies, while the old handwritten notes are progressing to electronic notes. Through this evolution offered by new technologies, such as Web 2.0 and mobile and ubiquitous computing, learning agents need to adjust to this new reality. Distance, electronic, and mobile learning offer methods, technologies, and content, which decrease the limitations of traditional learning. Mobile learning is an extension of distance education, supported by mobile devices (e.g., smart-phones or tablets). It is an emerging learning model and process, which requires new forms of teaching, learning, contents, and dynamics between actors. This paper proposes a system architecture that supports distance and mobile learning. This architecture considers four layers, supporting professors and students activities, and learning and evaluation processes through innovative and intuitive user interfaces. The system is supported by several technologies including context and location awareness, pervasiveness, ubiquity, and intelligent agents. It demonstrates how recent technologies can interact together to improve distant and mobile learning.

Keywords- Web Services; eLearning Technologies; Mobile Applications; Mobile Computing.

I. INTRODUCTION

Learning is a cognitive process owned by humans, which enables the ability to retain new or transform existing knowledge. The ability involves the synthesis of several information types over a period of time and, as a result, a person should retain that behavior or knowledge. The learning process requires, at least, two types of agents, the person who will be instructed and the content learning itself. It can be achieved through two distinct learning methods, the traditional at the classroom or at distance. The traditional method involves a physical and direct interaction between the student and the professor in a classroom, or any other physical location. The distance learning breaks the physical connection between agents, and uses new technologies to achieve this goal [1].

Electronic learning (e-learning) provides an opportunity for students interacting electronically with each other as well as with their professors. It is directly supported by a technology called Learning Management Systems (LMS). LMS is a Web-based application that provides services for administration, documentation, training programs, and e-learning programs [2]. An LMS may be seen as a middleware between the student and a diversity of entities such as a professor, learning content, and evaluation process.

Through innovative technologies offered by recent mobile devices, a new learning model called mobile learning (m-learning) emerged. Mobile learning offers people a new way of learning and an opportunity to learn anytime and anywhere. Under this approach, the physical restraints should not be seen as a real restriction, but rather a “user configuration”. M-learning can be achieved by the use of mobile devices, such as smart-phones or tablet computers. Due to the aforementioned specifications, m-learning is considered the next step of online learning by incorporating mobility as a primal requirement. Such devices offer an enormous range of technologies and potential to m-learning in terms of context and location awareness, ubiquity, pervasiveness, personalization, and flexibility [3].

This paper presents a learning system architecture to enhance current learning processes. It comprises the following four main modules: i) the LMS service aggregator and provider; ii) the necessary algorithms for all data mining; such tools will supply the system agents with central information; iii) a vast set of services aggregator that will provide abstraction of layers and data forwarding between internal and external system agents; and iv) the clients with the mandatory system requirements for system interaction. The architecture directly supports the learning process, professors, students, and the evaluation through innovative and intuitive user interfaces.

The remainder of the paper is organized as follows. Section 2 provides insights on available related work, while Section 3 presents the global system architecture focusing on its main components and their characteristics. Section 4 includes the performance evaluation and validation of the mobile application. Conclusions and future work are drawn in Section 5.

II. RELATED WORK

This section surfaces related approaches to LMS systems, focusing on its system architecture and its modularity (i.e., support for external modules, direct compatibility with mobile devices, existence of intelligent agents, and support with external platforms). Several projects with this purpose were proposed in recent years. The most relevant projects related with this topic will be considered, including some ongoing projects focused on mobile learning. For a better explanation of the projects, two categories of related work are considered.
The first includes pure LMS systems while the second addresses more diverse approaches for learning processes.

Blackboard is a well known LMS in the market since its services are used by over 9000 institutions in more than 60 countries [4]. Suite software provides solutions for various areas, such as, education, mobile, communication, and commerce. Each platform implies new module installation on server. Currently, it does not support intelligent agents, however, the support for native mobile devices and external platforms is robust.

SharePoint is a Web-based application platform created by Microsoft [5]. SharePoint is a centralized resources platform for multiple Web applications supporting various technologies; Moodle is an open source course management system, also known as a LMS [6]. It has become very popular among educators around the world as a tool for creating online dynamic Web pages for their students. Its architecture is based on two layers - a server and a Web portal for clients; MoMo (Mobile Moodle) is an extension of the Moodle platform and focuses on mobile devices [7]. It offers a new layer to the native system and provides the ability to implement m-learning scenarios with Moodle as a backend. Through this client users can access all the data anytime and anywhere. Since MoMo is an extension to Moodle, the Moodle administrators need to install the necessary MoMo extension on the server, which makes the compatible contents available for mobile users; Joomla LMS is a commercial component for Joomla content management system [8]. As the aforementioned technologies, Joomla is based on a two-layer architecture, the server and the client.

Haitao et al. [10] proposed a mobile independent learning system that can detect a mobile device context and adapt it. The devices (clients) can be the most diverse (from a computer to a mobile device), or any other devices that have the ability to access the network. The devices communicate between them through the server layer. When the server receives a request, it adjusts the answer parameters taking in account the client device, the bandwidth, among others.

Mahamad et al. [11] present a system to improve the education standard in Malaysia through the use of mobile devices. The system includes mobile quizzes and progress tracking. Currently, it only supports the Mathemathic course and neither other modules nor a modular approach are proposed.

Yu-mei et al. [13] propose a conceptual model that is supported by a framework for m-learning used in medical education. It includes multimedia, information interaction, management and monitoring modules, each one with specific characteristics and functionalities. Currently, it is under development and no experiments were performed yet. Licea et al. [14] designed MADEE (Mobile Application Development and Execution Environment), a platform that allows a student the development of easier and faster applications using conventional development tools.

Several learning frameworks and LMS were analyzed, each one with specific and common characteristics. The authors argue that learning and mobile learning process technologies should evolve and adapt to the current available technologies and devices. In this sense, next section presents the proposal of system architecture for achieving the aforementioned goal.

### III. System Architecture

The proposed system architecture considers several layers. Each one includes different characteristics and specifications, although all of them cooperate for the system homogeneity. The use of a multi-layer approach allows services abstraction and thus a better specification of each one. The proposed system includes a server, middleware abstraction, and clients.

The section starts with a description of the server side, including the PLEBOX platform and the core intelligence module [15]. Both are responsible for all the server structure and data processing. Next, a set of tools, including parsers to compilers and communication APIs are introduced. These components can be seen as a “man in the middle” between a server and clients. Clients include regular computers, smartphones, mobile devices, or even tablet computers. Figure 1 illustrates the proposed system model with its main components.

#### a. PLEBOX

The PLEBOX platform is located on top of the .NET framework. Unlike all other platforms, the concept of the PLEBOX goes through the idea of a digital “box” that contains different elements making use of the Rich Internet Application (RIA) and operating systems (OS) concepts. It follows a personal learning environment approach with integration of modern tools.

This platform provides a set of specific environments for each user. Each one contains several modules and features taking into account the user settings and configurations. So, each user has a unique environment personalized by him/her.

The system is totally modular offering the possibility to expand and increase the size of the “box”, allowing the installation of new or modified applications easily. Each application can be created focusing a particular objective or organization.

Nowadays, learning platforms follow a set of outdated guidelines and rules for content management, presentation, and formalization. Those guidelines have become obsolete.

![Figure 1. Illustration of the proposed system model.](image)
along the time and inappropriate to the students’ requirements. With PLEBOX, authors intend to introduce a new Web platform concept. The PLEBOX innovates on user interaction with the platform exercising concepts that only exist in non-Web-based systems, such as windows management, pure personalization of the environment, and ability to create and install external modules.

b. Core Intelligence
The core intelligence is the second component of the Server side and it directly supports the PLEBOX platform, providing the necessary tools for intelligent agents support in the system. This component provides intelligent mechanisms to achieve smart teaching environments [16]. It can be seen as an innovative technology, which is based on cognitive and thinking computer science, integrating several artificial intelligence mechanisms on educational models.

The objective of this core intelligence module is to deliver specific and adaptive contents to students in a smoother and intuitive way. In order to achieve such objectives the following features were performed on this module: a specific intelligent environment that directly support the learning process enabling the automatic generation of a variety of problems and exercises; capacity to explain the same problems and teaching contents; and generate and automatically solve understandable answers for all the teaching content. This layer provides users an evolutionary learning system, able to predict user profile, characteristics, and learning style. Such classifications will provide a way to the system for characterizing the students in groups and treat each one individually and in a unique way. Based on the aforementioned classifications the system allocates resources and adapts to users autonomously. Each group of students or an individual student will have specific characteristics and those characteristics will be taken into account when contents will be delivered. Plus, the Intelligence Core will redirect specific content to each user or to a group of users. Thus, each group is able to learn using its own characteristics and metrics, providing a true personalized and focused learning process. Moreover, evolutionary monitoring will provide tools for constant monitoring users and all the inherent features, characteristics, and processes. If at a given time any user has a specific problem or difficulty, the system adapts, and helping him/her to pass through it. The system will act and react accordingly when possible situations may occur with students.

For example, the student is reading about the C programming language and its functions. Taking into account the system is able to explain the functions in three different ways it will analyze how each user choose and how many times it will read about it. The next time the student will read about another specific programming language, the system will use the stored settings and adapt the content to the user. For a clean understanding, a flow chart was produced (shown in Figure 2).

Using this set of characteristics, the Intelligence Core is adapted perfectly to the system and to all the users providing a truly intelligent learning mechanism.

c. Middleware Abstraction
The middleware abstraction provides a bidirectional and constant communication between a Server and Clients. This set of APIs supports the communication among system agents. Despite being a transparent abstraction layer, it plays a key role in the system. It includes a modular middleware that provides the necessary tools for interconnection with external frameworks, APIs, architectures, and systems without loss of productivity, compatibility, or features, creating a broader computational system. Several specific APIs, such as database, learning, SDKs, among others, provide the needed and single tools for each system layer to communicate with each other.

The communication between layers and agents is performed through Web services (WS). In order to deliver the processing power to the corresponding services the system adopted the REST architecture by default. Specific PLEBOX WS provide an easy way for users to authenticate on the LMS. Plus, it will provide access to the user characteristics and definitions. These characteristics are human-computer-interaction based. It will provide a tunneling for content gathering, processing, and delivering.

Intelligence Core WS will afford the necessary tools for intelligent agents to navigate over the system and process the inherent information. Every time user requests information or the system delivered it, both WS work together to tune and adapt the corresponding information.

External LMS API is a set of libraries that provides the system with a connection to external LMS systems such as SharePoint, Blackboard, and others. Due to the fact of the system modularity this API provides a way to interact with external LMS and obtain all its contents in an easy and transparent way to the user and the system. The API provides methods for the internal system authenticating on external platforms, data retrieval, processing, and visualization.

External LMS WS will use the above-mentioned APIs and process data accordingly and correctly deliver it to the PLEBOX layer for internal data storage. Each time a new data set arrives to the system it is stored internally for performance, security, and robustly purposes. Due to the fact the platform uses and connects to external platforms to get new or updated data it is crucial that data may be organized in a specific data format to achieve data unification. Plus, storing external data internally will benefit from all the intelligent agents and raises the security mechanism to access the inherent data. The

![Flow Chart illustrating an exercise request.](image-url)
adopted internal storage data format follows the standard SCORM. Whenever the system retrieves data, despite the original format it will be stored using SCORM.

The specific WS client adds an intermediary layer for client authentication and data processing. It offers a transparent way to exchange and process data from/to the server layer. Taking into account the above-described characteristics and implementations the platform presents a robust and modular abstraction middleware that provides fully data exchange between all system agents in an almost transparent way.

d. Clients

The client layer is responsible for the user and system interaction. The user interface has three main sections that can be directly accessed: Main menu (left-side), Action-Bar (top) and the Central area. The Main menu is used for directly accesses the main application menus like Classes, Messages, Settings, or Assignments. The Action-Bar is typically used for quick searches, social networks interaction and access to the application support system. The Central area displays the information. Every time a user changes the menu or do an action, it will be directly reflected on the central area. This area is bigger to take advantage of the Tablet computers screen size. Both Main menu and Action-Bar are always available during the user navigation. However, the Action-Bar is dynamically modified depending the Main menu option and Central interface content.

Clients can range from a Web portal access to a smartphone, a mobile device, or even a Tablet computer. It is more than a simple user interface (UI) since it uses specific and new approaches, such as a totally dynamic, interactive, adaptable, and personalized UI. It presents the information to users in an innovative way. If a mobile device or Tablet computer is available, this UI layer includes context awareness providing users technology that does small tasks in a transparent and ubiquitous way without directly interacting with the user. For example, when an user requests a resource it will fetch the one that is more appropriate taking in consideration the current Internet connection settings. Moreover, users can automatically authenticate in certain defined locations, such as a university campus or a laboratory. The authentication can be performed though RFID, near field communication (NFC), or through specific and unique tokens generated per each user device over a wireless network. On certain scenarios, the context awareness can provide specific information to users using external devices, such as an information monitor. If more than one user is available on a specific context the system can interact and create a collaboration scenario among them. Furthermore, the users can take the advantage of their context and use external resources available on that context, like printing a document or use a projector or LED display for a presentation.

Location awareness offers to users a possibility to receive contents based on their current location and network typology. Adaptable content should take into consideration not only the user preferences but also the type of user network and location. The detection of network baud rate will provide a way to receive specific contents and avoid scenarios where users have a slow connection to receive large files size. Using location awareness, the system guarantees the access to the right information data type. Using such settings the system adapts itself and delivers content accordingly.

Ubiquitous and wearable systems can provide specific information about physiological parameters. The conjunction of learning systems with such technologies offers a wide range of information that can used to analyze and provide information to both system and users. For example, if a wearable system composed by sensors for temperature or heartbeat monitoring it is able to infer if a given user is stressed or not. Furthermore, it can study if that condition is responsible for his/her acts on the current system interaction. A large collection of wearable devices can be embedded on the system providing a robust and single learning experience. Since the system integrates intelligent agents and uses censored information, it can focus on particular topics for specific users (personalized learning). Using this set of characteristics the users can use a set of tools that provides an innovative mobile and intelligent learning environment. They can learn anytime, anywhere, and access the information that really matters since they learn in a personalized way. Due to the fact that mobile devices and Tablet computers market share are constantly evolving, a learning system that relies on those devices provides a strong option for those really want to learn and progress in a distant and mobile way.

IV. PERFORMANCE EVALUATION AND VALIDATION

The authors performed a set of experiments in the mobile application in order to evaluate and validate the proposed approach. The first main objective of this approach was the validation of the user’s interface, its organization, user experience, and configurations. In order to get feedback from students and their interaction with the system, a prototype was deployed on a physical device and given to them for experiencing.

The experiment phase took place between January 2 and February 16, 2012. During this time interval more then 140 students of the University of Beira Interior, Portugal (graduating in Informatics Engineering) were contacted to make the experience. From this universe, 117 correctly experienced the mobile application and filled correctly the survey questions.

The students used the application and experimented it on several scenarios (accessing and changing the user profile information; listing and accessing their current enrolled courses; listing and accessing their current assignments; accessing to a calendar style navigation interface, and changing several application settings). All the experiments followed a sequence of activities and took about 30 minutes each one, and reactions were gathered. At the end, a brief survey using the Doodle platform was filled in order to evaluate the initial user experience. The survey evaluated the
easy to access the information, personal configurations, and initial system scalability. The questions are found in Table I.

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<thead>
<tr>
<th>Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>Q. 1</td>
<td>Is the overall performance adequate?</td>
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<tr>
<td>Q. 2</td>
<td>Is the application easy to use?</td>
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<tr>
<td>Q. 3</td>
<td>Is the application user friendly and intuitive?</td>
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<tr>
<td>Q. 4</td>
<td>Are the navigation options clear and consistent?</td>
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<tr>
<td>Q. 5</td>
<td>Is the UI organization adequate?</td>
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</table>

The results of the survey administration are available in Figure 3. As may be seen, at least half of the survey participants strongly agree that the overall application performance and the navigation options are consistent. Other big number of users (45%) tends to agree that the application is easy to use. A small number of students (16%) tend to disagree that application environment may not be user friendly, intuitive, or the user interface may no be adequate for a learning environment (14%). These two questions are the ones that present more undecided students. It may occur due to the fact that users experimented a completely innovative application and a total different way to interact with contents.

Through this evaluation phase the authors can shape and adapt the development process in order to adapt applications to users needs.

V. CONCLUSION AND FUTURE WORK

This paper is a first step towards a new and innovative model architecture that relies on recent technology to directly support learning and mobile learning environments. A four-layer system architecture and corresponding development on the PLEBOX platform was presented. Each layer is responsible for the LMS management, intelligent agents, abstraction middleware, and clients, respectively. It also presents a mobile application that is fully integrated in the architecture and its layers.

Currently both students and professors have access to a wide range of learning technologies, however, new and innovative technologies can be used in conjunction to assist those approaches. Summarizing, the user will continuously access and use information anytime, anywhere using cutting edge technology of a wide range of computing areas.

In terms of future work the authors believe that learning processes, mechanisms, and agents will evolve to a new era, where technologies, learning materials, and people will directly interact in an almost natural way. So, the presented model may be adapted to cover all the aforementioned specifications. Plus, due to the continuous evolution of mobile devices, operating systems, and technologies, the proposed mobile application should be updated.

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