An Adaptive M-learning Architecture for Building and Delivering Content based on Learning Objects

Gabriela Andreea MORAR, Cristina Ioana MUNTEAN, Nicolae TOMAI
Babeş-Bolyai University, Cluj-Napoca, Romania
{gabriela.morar, cristina.muntean, nicolae.tomai}@econ.ubbcluj.ro

Mobile learning solutions have become a real interest due to the fact that mobile devices have a growing market share and have become somewhat indispensable to modern life. We propose an architecture for a context adaptive m-learning system based on learning object that, even if created by different standards, can be retrieved and combined with the help of semantic metadata processing. Our goal is to personalize the course content according to user context and preferences and deliver it bearing in mind the specific characteristics of the mobile device. We have developed the architecture starting from the results of a survey regarding m-learning environments and student's expectations from such a system.
Keywords: *M-learning, Context Adaptive, Learning Objects, SLOR, WURFL*

1 Introduction

M-learning is a concept that appears more and more often in the context of mobile devices and mobile technologies evolution. The learning process has evolved from the classical classroom teaching to the computer assisted learning and even further to e-learning and m-learning.

The main advantage of computer based learning is that learning resources can be accessed anytime and anywhere by using wireless or classical networks. Converging from computer based learning and mobile devices use, m-learning allows users to stay connected with the learning environment, learning resources, colleagues and teachers no matter where they are. Thus the learning process is no longer tied to a certain location and depends only of the willingness of the learner in accessing the learning resources. Devices classified as mobile vary from notebooks to smartphones, PDAs and tablet PCs.

Some of the main challenges that arise in the use of m-learning are: the access to information from devices that run on different platforms and the different capabilities of those devices.

The first challenge can be addressed by implementing a MSOA (Mobile service oriented architecture) [1]. By using this approach, the requested services are provided by web services in an easy to use format and by using standardized interfaces.

The mobility of the devices and the use of web services make MSOA the ideal solution for delivering information independently from a platform. This allows a wider variety of devices to access the service and interact with one another. MSOA brings not only internal integration but also extensibility among the relationships present between actors and devices.

Regarding the second challenge, due to the restrictions arising from mobile device capabilities, information that is to be used within m-learning systems must be substantially different from the one used in previous learning environments. Thus the content of learning materials has to be restructured in order to fit to the rendering capabilities of mobile devices.

Such examples are very long learning materials that do not match the requirements of m-learning. Thereby the content of the courses has to be structured so that the information could be delivered in smaller segments that are well organized. The course content will be adapted to the rendering device, thus only the essential information will be displayed. The learner has the possibility of choosing whether he/she wants to access the entire information or only a part of it.

The mobile devices taken into consideration for the m-learning process use different operating systems [2]: Symbian OS, RIM BlackBerry, Windows Mobile, Android, iPhone

OS, Palm OS, etc, thus making it difficult for an m-learning application to run properly on all of the above operating systems. An example in this context could be the fact that many Smartphones can support MIDP (Mobile Information Device Profile) 2.0 regulations, by running Java 2 Micro Edition (J2ME), while others do not.

Based on a survey made among Babeş-Bolyai University students, we have observed that many of them are familiar with the concept e-Learning and more than 80% of them consider that an online learning application could help them in the learning process. Regarding the concept of m-learning only 25% of surveyed students are familiar with the term but 84% of them have expressed the willingness of finding out more about the use of mobile devices in the learning process.

In order to solve the above mentioned challenges, we have proposed architecture for delivering content to various platforms based on a context adaptation model.

2 Related work

Further we describe the main concepts used in the specific literature and also used by us in the proposed architecture.

Mobile learning (m-learning) is a concept that describes the process of learning by using mobile devices. Mobile learning [3] can be achieved by using mobile devices such as PDAs, Smartphones or notebooks and it is represented by the acquisition of any kind of knowledge and abilities based on the use of mobile technology, anytime, anywhere.

A learning object (LO) [4] is any digital resource that can be used within the learning process. Thereby a LO is any entity/resource that can be delivered within a network upon a request, regardless its dimensions. These resources can be digital images, photos, audio/video files, text, animation, small applications considered as small size resources, or resources that are larger in size such as: web pages that include more from the above mentioned elements. Initially the LO definition included any entity, digital or not, that could be used in the learning, educational or training process.

LO [5] are characterized by metadata, thus facilitating the selection and integration of learning experiences from small LO libraries. Metadata makes it possible to search and retrieve LO based on a learner's request. LO are stored in dedicated databases called LO Repositories.

Semantic Learning Objects Repositories (SLOR) [6] are semantic databases containing LO. Here, the LO are being stored along with their metadata descriptions and the interaction with other similar repositories is facilitated through the available interfaces. The majority of these repositories are specialized in storing LO metadata, based on which the LO are retrieved from different locations and combined. SLOR facilitates retrieval of LO based on their metadata.

WURFL [7] is an XML configuration file that contains information about the features and characteristics of many mobile devices.

In [8], [9] and [2] a variety of m-learning architectures and content adaptation and delivering models were proposed.

Contributions to the content distribution within m-learning environments where made in [8], where a model for e-courses distribution is proposed and general concepts regarding m-learning and mobile devices capabilities are presented. Three types of content distribution are described: AvantGo Mobile Internet Service, online access via telephone to the entire course and a download on demand version. Learning Objects content is adaptable and can be delivered in more file formats: XML (feed), HTML, PDF, doc, etc. For creating LO they use SCORM (Sharable Content Object Reference Model), which sums up the specifications for building LO. The architecture proposed by Mahmoud contains a model for an agent-based web learning system. It is based on LO, a Grid Engine for building e-courses and GSFL. He mentions the fact that for adaptation purposes an XML file is built, which later can be converted into the necessary formats.

In [9] the focus is mainly on the context adaptation model of the delivered content. This model uses Bayesian Belief Networks

for creating content based on LO. The major advantage of the proposed model is the reusability of LO and its adaptability according to four major factors: context (user location, date/time, noise level, and resources availability), user, connectivity and device.

An example of existing relationships among the four mentioned factors is presented in figure 1.

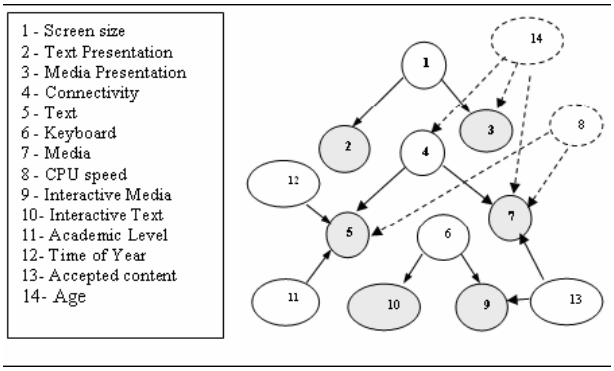

Fig. 1. Bayesian Belief Network [10]

In [2] an adaptive model based on user and domain models is proposed and it is emphasized that these two should be in connection with the pedagogical model and pedagogical rules in order to create a better learning process even on mobile devices where the content format is lighter. In [9] and [2] the sequences of the course are different for different users and contexts in order to achieve pre-established learning objectives. The proposed system is complex and the content adaptation is based on multiple factors such as noise level, time/date, learners concentration level, and users preferences regarding his/hers learning style, material types and difficulty level. The Bayesian model is used for de determination of the learners' learning style, content individualization and improvement of the learning model.

3 Proposed Model

In this paper we have proposed a possible architecture for a m-learning system, which includes several learning process dimensions, from the creation of content for courses, transforming them in LO and the composition of courses based on created LO to delivering them to the mobile devices according to context and users preferences.

The architecture focuses on the creation of an adaptive model for content delivery. The proposed model is adaptive from more points of view:

- LO and XML format can be used on any kind of platform, XML format is recognized as platform independent and easily adaptable. Courses are initially in an XML format. According to the device that makes the request, they will be converted in an appropriate format.
- The course content is also adaptable because it is being created sequentially according to user's requirements.
- The other adaptive dimension is the delivery of content according to the capabilities of the device from which the request was sent.

Every individual has his/hers own learning style, a factor that cannot be let out when delivering learning content. The way in which the learning style is reflected in the course content can be retrieved from the capacity of the system to deliver content in various formats. To be more precise if a learner has visual memory (learns faster and easier based on graphical elements rather than based on textual data) he can choose to receive content based with preponderating on visual elements. In the same way if the required outcome is a faster loading of data, a textual content will be preferred to a visual one. In [11] five dimensions that can influence the learning style are being identified: active/reflective, sensory/intuitive, visu-

al/auditory, sequential/global and inductive/deductive. We also kept in mind these learning styles dimensions when creating the user profile on which the information is delivered.

Based on the results of the conducted survey, we can state that every person participating at the survey owns a mobile device and over 50% of them are willing to use that device in the learning process. When questioned about the file format they use more often on their mobile devices the results were the ones presented in figure 2.

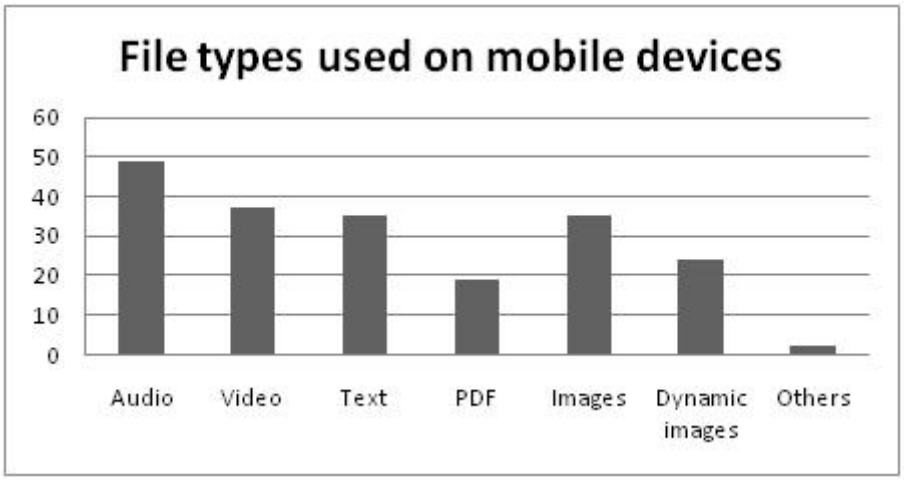

Fig. 2. File types used on mobile devices

Even though the course is created in a sequential way, following the adaptive model, the user will initially receive the course in a small format based on which he will have the control on which elements he wants to access. The course is structured as a tree, composed of LO interconnected by hyperlinks. Once the learner goes deeper into de tree structure the level of detail grows along with information complexity, thus the learner can also influence the customization of the material and he/she can model it according to his/hers learning style or time preferences that the system is not able to identify.

The workflow in the proposed model is the following:

- The user files a request to the system based on his/hers profile and context in which he is located and device characteristics.
- The Adaptation System (an intelligent agent) identifies the LO that correspond to the request and, according to the user preferences and mobile device characteristics, creates the course based LO that fit the required parameters.
- After the best solution is found, we have to test if the proposed learning objectives are met and if the course format is an appropriate one. If the course is validated, it is then delivered to the learner.

Based on the outcome of our survey, the main type of content for the learning material required by learners are: courses, tutorials, quizzes and others. The more desired ones were tutorials followed closely by courses and seminars.

The proposed architecture has also taken into consideration the restrictions on the mobile environment that were described in [12]: restrictions regarding computational power, restrictions regarding the quantity of information transferred, connection duration and limitations that arise from the used terminal.

4 Systems Architecture

The proposed architecture is based on the creation of courses from LO and their delivery towards mobile devices according to their features and capabilities.

In [2] there were identified some principles that must be respected when designing the mobile client application: adaptability to more platforms, efficient consumption of re-

sources, limited interaction between user and the device, use of limited bandwidth and not requiring additional hardware.

We focus on the model of content distribution according to device capabilities, the adaptation of the course to the data formats and the display capabilities of the device. Due to lack of standardization among mobile device capabilities it becomes a challenge finding a method to display course content in an efficient manner so that it best fits the characteristics of the device that is accessing it.

Due to rapid development of mobile devices, the challenge of adapting LO content to the characteristics and capabilities for rendering various media files formats, without needing to rewrite the already existing LO, still remains. We find it appropriate to keep the course content into XML format that later can be transformed in the required format. By keeping the content into small segments, we can achieve a grater granularity of information, which will later allow us to compose more complex LO based on the simple ones. Having in mind the fact that LO are described by metadata, we can easily identify semantic web ontologies as a method of searching LO that are similar, but which are being described in different ways.

Architecture Components

The system is divided into three main parts based on the data processing:

- Introducing data into the system (creation of LO and connections amongst them);
- Retrieving LO based on the requests made by users;
- Delivery of the resulted LO according to mobile device characteristics.

The results obtained based on the request are filtered according to context characteristics. The context in which the learner is positioned is composed of different data that can be obtained in several different ways:

- Some data is delivered directly by the student when he creates his account into the system, moment in which he/she can specify certain preferences that he/she has (learning style, file formats preferred, etc.).
- Data regarding the location of the learner can be retrieved using LBS (Location Based System) that will identify de geographical location of the learner.
- The capabilities of the mobile device are another component that characterizes the user context (these will be identifies using WURFL). Based on the data retrieved using the above mentioned methods the user profile is created.

The propose architecture is presented in figure 3.

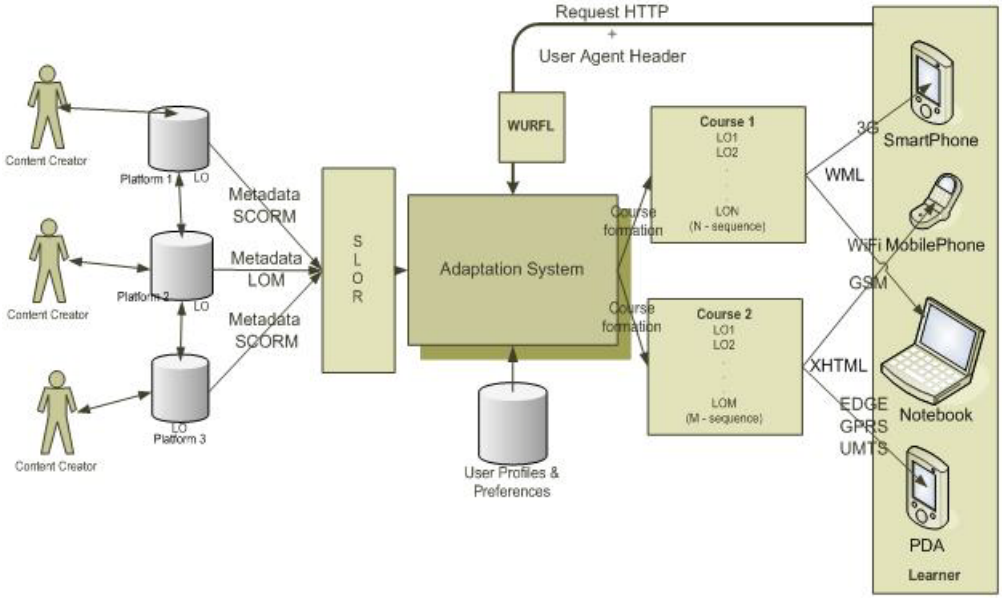

Fig. 3. Architecture components

After the implementation, an evaluation of the proposed architecture in real life situations will be made in order to adapt it to user needs.

Also as parts of the survey results, we have identified the main expectations and concerns that users have when it comes to using m-learning systems. Figure 4 and figure 5 presents the obtained results:

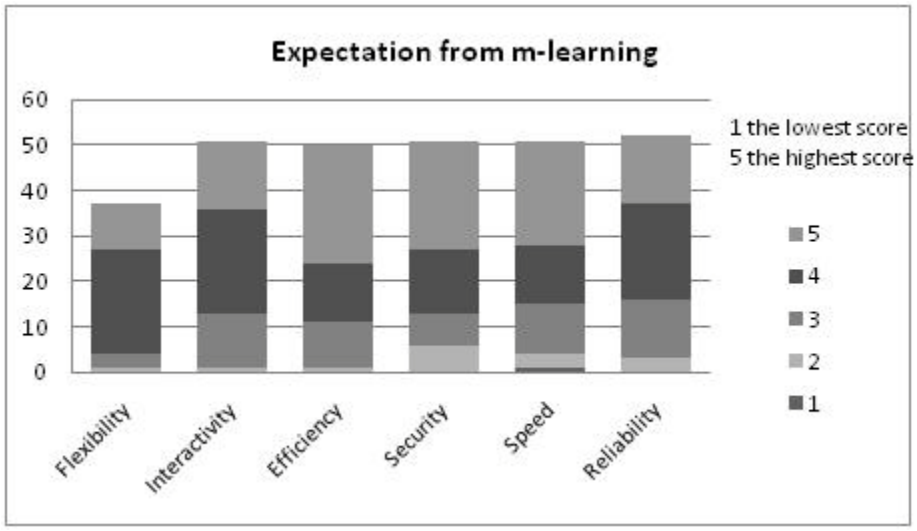

Fig. 4. Expectation from m-learning

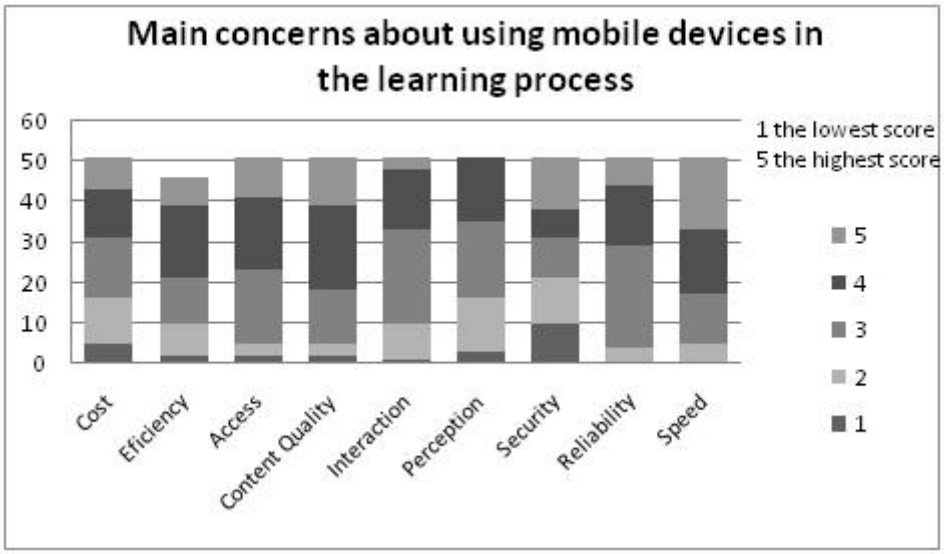

Fig. 5. Main concerns about using mobile devices in the learning process

The size of the information that will be delivered to the requester is crucial; meaning the synthesis of information is a must. When m-learning systems were first created the memory space and processing speed were a big issue, but it the last few years the technology has evolved, the size of information delivered to the device is not that crucial anymore, duo to high speed processing on mobile phones. It is more important the way in which information is displayed. Thereby due to technology development it may be easier for the learner to access and go through audio and video material than to read big amounts of text, especially if they are using a mobile phone that has a smaller screen and limited navigation possibilities.

We have chosen to work with the concept of learning objects because they are suitable for the composition of courses. This allows flexibility, as the content can be structured in small segments that can be accessed in an

easier way than an entire course and content can be reused and combined. A single LO can be a part of one or more courses.

All LO are described by metadata, but due to the fact that the structure of this metadata varies according to the repositories in which they are situated and their description is not uniform. There are multiple standards that are used in describing LO; the most common are LOM and SCORM. Also the metadata description of a LO is written by his creator and this may cause identical or very similar LO to be described in different ways.

In [13] a way of defining the complexity on LO is proposed. The three factors that are presented in Table1: aggregation level, interaction type and resource type can help classifying LO according to their complexity. These properties are a part of the IEEE Learning Object Metadata (LOM) standard [14] that was approved in 2002.

Learning objects can be created directly by a LO-creator or they can be taken from already existing LO Repositories. When combining the two kinds of LO an issue might appear because of the fact that they are created with different standards. Upon a request from a user the Adaptation Engine might not be capable of finding all available LO due to their different descriptions.

Table 1. IEEE LOM standard

Types of LO based on elements from the IEEE LOM standard
Aggregation Level First level: refers to the granular or atomic level of aggregation e.g. Simple images, text segments, or video clips. Second level: refers to collections of atoms e.g. HTML documents that include images or lessons Third level: refers to collections of second level objects. E.g. A series of HTML pages linked by a index page. Forth level: refers to a wider level of granularity, e.g. A series of courser that lead to a certificate.
Interaction Type Expositive: information flows from the object to the learner and includes: text, audio, video, graphics and linked HTML documents. Active: information flows both ways. E.g. Learning-by doing, simulations, different kind of exercises. Mixed : a combination of the other two
Resources Type Resources can be of the fallowing types: exercises, questionnaires, diagrams, figures, slides, tables, text etc.

Assuming that when a request is submitted there can be found both LOM and SCORM described objects, it becomes difficult for the system to compose complex LO with simpler LO that have metadata created with different standards. For this reason we have integrated a Semantic Learning Object Repository (SLOR) into out proposed architecture.

The SLOR prototype [6] was created precisely for the creation and management of LO, with focus on the integration and interoperability with different similar systems. Compared to other repositories, SLOR brings out new functionalities, most residing in ontologies and semantic web middleware tools, which are the basis of its foundation. They allow reasoning and inferences upon the metadata of LO. With the help of SLOR, it is possible to search, identify and group LO based on their metadata.

The adaptive system for content and course formation, as mentioned earlier in the text, takes into consideration the factors that intervene in the customization and personalization of the course based on the mobile device and user. This intelligent system creates the

course from LO, after receiving a HTTP request from the user, taking into account the user profile and the capacities of the mobile device identified with the help of WURFL.

The Bayesian Belief Networks model used in building sequential course content is a representative model for adaptation to context. The variables of the Bayesian model in [9] are: mobile device limitations, connectivity, learner profile and content type. According to context and preferences, LO are dynamically added to the course, which in this manner becomes more personalized. This approach is focused on the learner and context.

Following the proposed architecture, after the course has been created from the LO identified with the help of metadata and confronted with the user requirements, references and mobile device capabilities, the course is finally delivered to the issuer of the request, the learner, in a convenient format [15].

Although the characteristics of mobile devices vary from one model to another, in [16], the characteristics that we found relevant to our research, more explicitly to the way the delivered information is rendered and presented to an m-learning device, have been identified as follows:

- Screen resolution - This component is essential when it comes to adapting the content to the receiver. Currently there is a big variety of available display solutions – from the small resolutions of mobile phones, to the big ones of notebooks [17].
- Display mode (portrait or landscape) – the display mode is implicit for some mobile phones while for others like PDAs or smartphones allow user to switch display modes from portrait to landscape and vice versa. In this context it becomes important to identify not only the resolution of the screen but also the display mode in order to render the material in the appropriate format.
- Markup languages and supported scripts - Determining these characteristics is important in order to adapt (X)HTML web pages using JavaScript, because not all the mobile browsers on PDAs or smartphones are able to display these functions. Mobile phones that subscribe to the WAP 1.X standard allow WML and WMLScript, while the ones that subscribe to WAP 2.0 allow XHTML.
- Supported multimedia file formats – It is important to determine these supported types in order to transmit to the users only those LO that can be rendered by the mobile device browser.

Based on the questionnaire we have identified the main types of mobile devices, the most popular browsers and mobile applications used by students. All questioned students have at least one mobile device, the main one being the mobile phone. Many also have laptops and only a smaller group has smartphones or PDAs. The most popular applications of mobile devices are voice calls and SMS, followed by Internet browsing, e-mail and social networks.

There are many available methods of determining the characteristics of mobile devices. Currently this can be done with the help of the HTTP Request Header [16] by the servers and proxies. The way the information is stored in the user-agent header however, depends from one producer to another, this being the main reason why other options are preferred when it comes to identifying characteristics other than the ones regarding producer, model and used browser. The characteristics and features of mobile devices are various and identifying only the ones available in the HTTP header might not be sufficient in order to display properly the information to the user.

Some of the options used for finding other information related to the mobile device capabilities, apart from the ones in the header, are through the W3C Composite Capabilities/Preferences Profiles (CC/PP), the WAP User Agent Profile (UAPROF) standard and Wireless Universal Resource File (WURFL). For our architecture we have decided upon the latter in order to identify the extended characteristics of the mobile device.

Wireless Universal Resource File (WURFL) [7] is a configuration file that contains data in an XML format regarding the characteristics of the mobile device available on the market.

The main goal of this file is to collect as much information as possible about the mobile devices that access WAP pages, in order for developers to be able to build better applications and services for users. This is an open-source project built especially for WAP and Wireless applications developers. The reason why from all available options we chose WURFL is because this one allows modeling of mobile device characteristics and it can be stored on a server, so we do not need to access it in a remote mode.

The display of the content to the users according to their devices is done with the help of XSL files [15]. Base on the XML files transmitted from the system and the type of device of the learner, the course is displayed in a certain style. The considered mobile device, from a display and data processing point of view are divided into categories as follows: low, medium and high. The style is applied according to the category the device is part of. A preformatted style file is run on the device.

The way the data is rendered to the mobile devices [17], especially the ones that have a smaller size like mobile phones, smartphones, PDAs and others, is considered important. Due to the fact that there is no actual size standard for them, each manufacturer uses their own specification and thus dimensions. We are limited by the resolution of the screen, the processing power, the memory and connectivity. Bearing in mind these limitations in [17a, 8, 23] a focus and context visualization algorithm is proposed, algorithm which allows the user the possibility of detail visualization of certain areas of interest on the screen.

5 Conclusions and future developments

In order to identify the need for mobile technologies in the learning process, we have questioned students in final years and master students from the Business Information Systems specialty at Business and Administration Faculty from Babeş-Bolyai University. We considered them as being a well established target group due to the fact that they are in contact with recent technologies, and learning through the help of mobile devices would fit for this area of study. Based on the results and identified needs of the questioned students we came to the proposal of such an m-learning architecture for designing a flexible and context adaptive system, contemporary with the evolution of mobile devices, browsers and applications.

Through m-learning we can deliver courses, seminars, laboratory notes, tutorials, quizzes and useful references for a comprehensive and up-to-date learning process.

After analyzing the results we could observe the students' wish to enrich their learning experience through the use of m-learning applications. As a future development for the proposed architecture is actually implementing such an m-learning system that can be initially tested for a well targeted group which addressed a particular field of activity, but that can later be extended to more fields by adding features that allow us to integrate useful resources for each activity field.

The current architecture offers a solution for m-learning course formation with the use of LO, a solution that combines recent technologies and that is comprehensive from the point of view of the analysis. The architecture presents an adaptive system for content delivery in m-learning, in the context of reusing existing learning object, but integrating news ones as well. Even if until now we have not mentioned any social model for the actors and courses of the system, we wish to consider this as a future development, namely building a community for the users, groups and interaction features as well. As a future development we wish to integrate a module focusing on student assessment and the development of the student interaction with the teacher and the course, allowing him to make annotations, stock information locally and send feedback. In the user profile we could add a tagging system that can help the learner navigate fast and easy through the content or the already revised materials.

The student, teachers and mobile devices are important actors in the system, that's why as a future development we can create a student alert model with the use of mobile technolo-

gies, we are currently thinking of SMS.
The advantages of developing such an m-learning platform are numerous, but due to the fast technological pace in this field, any system requires a very adaptive approach in order to be viable. For this reason we believe that the LO based architecture fit the context. There are numerous existing LO repositories, even if on different platforms and created with different standards. These objects have the advantage of being reusable and adaptable through their metadata, because even if created differently they can be aggregated and unified by SLOR.
Another challenge in m-learning is the efficient delivery of content to the mobile devices. These devices are different and not created according to an imposed standard, thus the need for adaptation to the characteristics of the device. The customized delivery according to device, the type of connection and other aspects will be taken into consideration.
The current architecture focuses on flexibility and adaptation rather than the actual study material sent to the learners. The emphasis is on the way retrieving and combining reusable LO, combining LO into courses with the help of intelligent agents and distributing it to learners. The adaptive engine will be describes in a future paper and according to it an intelligent agent prototype will be created. The m-learning course should have an optimum quantity of information, offer easy navigation and visualization and more importantly reach its learning objectives.

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Gabriela MORAR has graduated the Faculty of Economics and Business Administration, Business Information Systems department from Babes-Bolyai University of Cluj-Napoca in 2008, later specializing in a master in Business Information Systems and Information Society. Her doctoral orientation is towards studying Service Architectures in M-Business and developing an efficient service negotiation model. She is interested in programming languages, wireless networks as well as peer-to-peer in MANETs.

Cristina MUNTEAN has graduated the Faculty of Economics and Business Administration, Business Information Systems department from Babes-Bolyai University of Cluj-Napoca in 2008, later specializing in a master in Business Information Systems and Information Society. In her doctoral research she is studying Business Intelligence techniques like web mining and applying them in order to improve website performance. She is interested in data mining, web technologies and Internet marketing.

Nicolae TOMAI is full Professor at Faculty of Economics and Business Administration, Babeş-Bolyai University of Cluj-Napoca. His main research areas are: Fundamentals of Computer Science, Operating Systems, Algorithms and Data Structures, C ++, C#, Computer Networks and Distributed Systems, E-business. His work includes 19 books, 59 scientific papers published, 1 patent, innovation patent 5, active member in 18 research contracts.