Integrating a multi-agent recommendation system into a Mobile Learning Management System

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The paper presents the guidelines of a project of three italian Universities (Bologna, Siena, Trento) which aim is to integrate a multi-agent recommendation system that suggests educational resources to students into a mobile learning platform that supports mobile learning processes in a University context. The project covers three main areas. The first area is concerned with finding effective models for mobile learning. The second regards the evaluation of learning processes in mobile learning environments. The third focuses on the technological aspects of integrating the multi-agent recommendation system into mobile learning management system. The project has its foundations in the availability of significant experience on e-learning real processes, and on the availability of the source code of an e-learning system developed in previous projects and currently used by different faculties. In this framework we will integrate InLinx, a multi-agent Web-based hybrid recommender system that provides a on-line bookmarking service in our m-learning architecture.

1. Introduction

Mobile learning is a field which combines two very promising areas – mobile computing and e-learning. Mobile learning could be considered any form of learning (studying) and teaching that occurs in a mobile environment or through a mobile device, like cellular phones, Personal Digital Assistants (PDA), smartphones, tablet PC etc. On the other side of mobile learning, we have e-learning, i.e., every educational process assisted by computers through the networks, and Internet in particular. M-learning has been considered as the future of learning or as an integral part of any other form of educational process in the future.

As m-learning is quite a new domain, there is a lot of work and research that is presently going on. Specifically, people are trying to understand:

- which learning models can help obtaining better learning processes when communication is mediated by mobile devices, and how the student mobility affects her/his learning process.
- how it is possible to evaluate efficiency and effectiveness of learning processes based upon mobile technologies, given the physical limitation of mobile devices.
- which services are useful for mobile devices, which is the enabling technology that can affect the wide diffusion of mobile learning.

A mobile learning educational process can be considered as any learning and teaching activity that is possible through mobile tools, or in settings where mobile equipment is available. National and international researches in the m-learning field are geared towards some lines that we shall here overview. Different devices that exist and all the devices that are coming up on the market, with their limitations and advancements, provoke different ideas for applying them on learning, thus any device can mean different m-learning. Among the open problems, some are relative to the pedagogical use of mobile devices. Since the m-learning term appeared for the first time, some research has been done to investigate the cognitive and pedagogical aspects.

Investigation had been done also on how useful mobile computing devices could be for reading or for workplace activities [1], on the basis of studying activity theory. Some authors [2] try to give directions to application designers for the areas, where the mobile devices should be most useful. Others [3] are trying to achieve conclusions by analyzing the theories of adult informal learning. In a few papers some interesting positive sides of using new technologies are underlined i.e. the participants are excited and want to try "new" things.

Some findings show that introducing new forms of teaching (even if this means just using a standard tool for drawing on a PDA) make students spend more time in working on that subject, comparing to the other subjects.[4] The currently evolution and analyses of m-learning projects show many positive results. On the other hand there are some doubts if this excitement is, or is not, a temporary side effect. Most of the researchers think ([5][6]) that PDAs and other mobile devices should be seen more like extension, rather than replace the existing learning tools. Moreover not all kinds of learning content and/or learning activities are appropriate for mobile devices [7].

The experience from years of development and use, the advance of technology, and the development of tools both for mobile services and e-learning techniques have resulted in a sophisticated, computer based m-learning system. However, there is still a lot of room for further development. Some of our current ideas toward the development of this field are discussed in this paper. In particular, we'll present a project of our three Universities in which we want to use an existing Learning Management System and adapt it to the needs of mobility, having the source code of the system available. This mobile platform will be used to test principally new models for learning in mobile settings and tools for assessment of learning process through the use of mobile technologies. These objectives will be pursued through:

- The adoption of a well tested e-learning platform adapted to the usage of mobile devices
- Implementing mobile computing services in a University setting
- Studying learning models linked to mobile technologies
- Studying learning evaluation models based in an m-learning environment
- Design and development of Learning Objects suited to mobile learning, together with services for evaluating their effectiveness
- The experimentation of prototypes built in real learning processes
- The integration of an hybrid recommendation system based on agent technologies able to effectively filter relevant resources from the Web, taking advantages of the shared interests among students.

Designing applications for supporting the student on accessing Web information sources is one of the current challenges for the Artificial Intelligence community. Agent-based solutions represent a natural way of facing this problem, since the above requirements lead to software systems that autonomously react to user actions and continuously learn, from his behaviour. In particular, dealing with open and dynamic environments requires systems based on multi-agent systems technologies. By combining appropriately agents working cooperatively over space and time to solve a variety of complex problems, that are beyond their individual capabilities, multi-agent systems (MAS) are an important paradigm for building complex information systems, especially cooperative ones, that explicitly and systematically deal with aspects of cooperation and change. In this framework we propose to introduce InLinx, a multi-agent Web-based hybrid recommender system that provides a on-line bookmarking service in our m-learning architecture.

The paper is organized as follows: first we will briefly present the three elements that in our opinion help to build a mobile learning environment, i.e., models, evaluation systems, and back-office tools. Next, we will focus on the evaluation of learning processes that offers interesting opportunities to introduce the need for personalized criteria; in fact, we consider fundamental personalized information classification and filtering facilities to use the huge amount of digital information according to the student's personal requirements and interests. In this way, data can be obtained about which material is proving to be most effective in raising student achievement. Taken together with the profiles of student strengths and weaknesses, this may prove an effective tool for identifying which resources are most suitable for each student, giving them an individual program of study, tailored to their needs. The paper also introduces a paragraph that investigates how to smartly manage information using agent-based software systems and offers some useful links to related works.

2. The three elements of building a mobile learning environment

As said in the introduction, the aim of the project has three key elements. Firstly. we are interested into analyzing and viewing the system as whole and thus researching, whenever it would be possible, models that would allow us to individuate the relationships that connect those elements, as well as their knowledge value and reach. Therefore, the concept of model becomes the basis to connect the learning process with the languages, the methods, and the tools that are employed to implement and experiment the Virtual-Real Learning Communities. Such communities should deliver evaluations of the result of learning process and objective measurements parameters, which are (possibly) independent from the teaching contents .

A second but not secondary issue is concerned with how to evaluate the m-learning tools and their model as a function of the induced quality in the learning processes. Talking about good quality in distance learning is undoubtedly a not easy task. Not easy for various reasons, first among everybody because has not closed the debate on what he understands, in more general sense, for quality of a formative intervention, with all what which this involves yet: didactic effectiveness, social and professional impact, investment, etc. We would like to assume for quality not as much the excellence as rather the management of a continuous process to approach the most possible the wished effect (for instance, what one wishes is learned) to real effect (what which has been learned). We call such systems closed ring, key element of this kind of systematic realignment is a constant monitoring aiming to the evaluation both of the users and of the whole process. The system of new generation which we intend to develop is

based on the interaction of all the parts of the process, to give way to the distributor of the formative action, to monitor the process and to regulate it, when necessary, wished to redirect it adequately toward the effect.

A key element for this is a constant monitoring, whose aim is to both evaluate users and the whole process. The new generation tool that we intend to develop is based on the interaction of all process components, so as to allow tutors to monitor and steer the process. In such way it will be possible to achieve a better coherence with the stated objectives, making therefore easier to reach the desired goals. Possible answers to these problems are presented in [8]. In the context of the present project we would like to highlight two particulars. First of all, the personalization of the tests is possible only in presence of a student model that memorizes a description of his expertise and brings up to date. Besides, the enlargement of the field of action of the evaluation, from the results to all the educational process, makes it possible the use a graph structure.

As a third key element of the project, in order to support the experimentation of any tool or technique of m-learning, a rather complex information system is necessary. Its role includes distributing didactic material, users identification and authorization, gathering of data relative to the user-system interaction, provisioning of mobile services, supplying statistics on level of usage and satisfaction etc. The main areas in which the mobile prototypes will be developed will use PDA, and portable devices in general, as mobile interfaces to the information system. At the current state of the project, three main areas are investigated :

- The use of PDA as an enhanced organizer, by uploading/downloading data with the central system in order to align periodically or on demand the agenda of the user (teacher, student or other actors of the system) with all the academic appointments. This will imply the integration of the data schema of the agenda software of the portable device with the data coming from the central system.
- The browsing of newsgroups managed by the central Learning management system (LMS) on the PDA screen, in case the user has no keyboard attached to the portable device, or the full interaction with the newsgroup in the other case.
- The browsing of the LMS web pages where it is possible to download the educational material and consult it with specific viewers (at the moment, those related with the Office™ suite and with Acrobat™ PDF format)

All this work will imply the adaptation of current dynamic pages that build the LMS to the mobile devices, by reviewing all the graphics, the different alignment of video elements, the adaptation of contents of the various pages of the LMS to the screen of different PDAs. Furthermore, we are experimenting techniques for guaranteeing the no messages are lost even when the device is out of coverage.

From this point of view, the project attempts to interconnect m-learning technologies with e-learning, and e-learning is in turn always more integrated in the information systems of academic institutions. The huge amount of data collected by this information system regarding user interaction with the system itself and with other users will constitute the base for feeding InLinx, the hybrid recommendation system we want to test in mobile environment. The idea is that a multi-agent recommendation system that suggests interesting educational resources to the users of the system will be extremely useful, and that mobile technologies will improve the communication between the system (and its InLinx component) and the end-user.

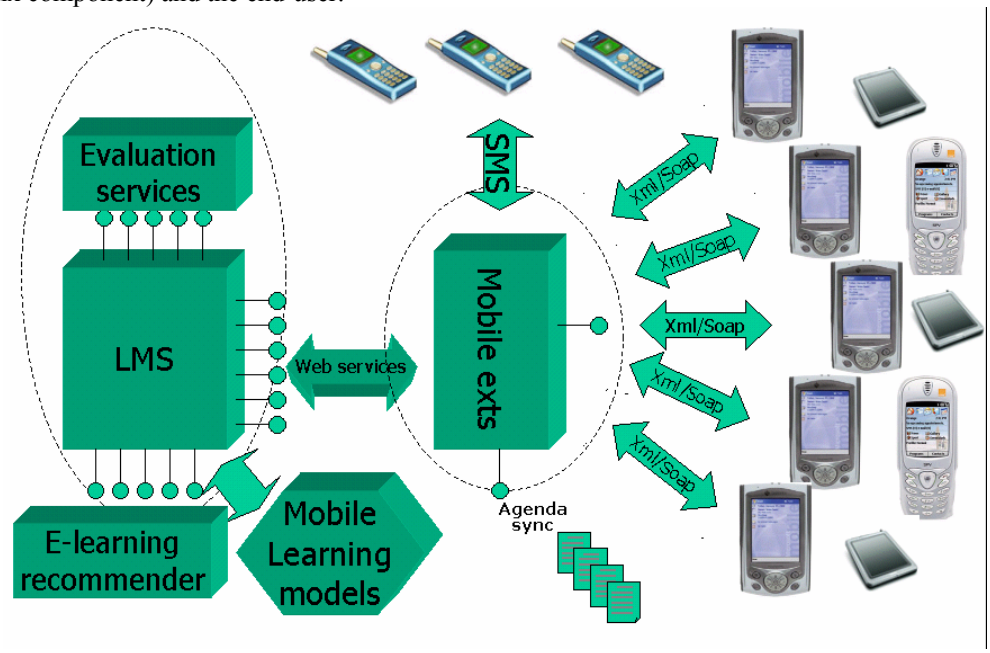

Fig. 1: A general schema of the prototype

In fact, information filtering systems can help learners by eliminating the irrelevant information, operating like mediators between the sources of information, the LMS, and the learners. Personalized filtering should be also a process of filtering based on not only the long-term interests, but also the short-term requirements. For these purposes, we consider relevant the integration of an hybrid recommender system that combine content analysis and the development of virtual clusters of students and of didactical sources. This information management system provides facilities to use the huge amount of digital information according to the student's personal requirements and interests. In this way data can be obtained about which material is proving to be most effective in raising student achievement. Taken together with the profiles of student strengths and weaknesses, this may prove an effective tool for identifying which resources are most suitable for each student, giving them an individual program of study, tailored to their needs. Moreover, InLinx can find application in any context in which the group collaboration is a requisite, and we believe that a Web-based learning system is an ideal application domain. E-learning systems, and LMS in particular, are nowadays a key element in the learning processes that take place at Universities, and they are widely investigated in literature [9], [10], [11], [12]. Several implementations are available on the market, like for instance LearningSpace™, WebCT™, Blackboard etc. [13]. They are in the middle of a transformation from simple support of on-line learning (like in the case of LMSs) into real information systems (Learning Information Systems -LIS). As such, they integrate many components of the wide spectrum of a formative action [14]. Our project needs to integrate such systems with our project's specific mobile-computing requirements. This means that we have to focus mainly on two points: on the one hand we have all the administrative and back-office processes of a Faculty (e.g. exam registration, didactic design, theses management, bookkeeping of teachers activity, University marketing etc.).

On the other hand, research attempts to focus on the technological evolution that brought to people mobility and mobile terminals (PDAs, pocketPCs, cellular phones, smart-phones, tabletPCs etc.) that are now present in every day's life. These tools are an interesting for a LIS, since they allow the various actors (such as students, teachers, administrative personnel etc.) to have a mobile platform that keeps them in touch with the LIS wherever they are. The possible applications are therefore very many: we can for instance think at the possibility for a secretary to communicate with mobile-technology enabled students, or at possible mobile collaboration among teacher and students within a course framework (our research will explore this aspect).

Some work has been done on Learning Management Systems, but the idea of a University Information System having a mobile component that belongs to the skeleton of the Information System is still in its infancy. It is therefore clear that it is not possible to be concerned with single classes of actors without considering the whole picture, since LIS aggregates users with different roles. The focus therefore moves from a system dealing with "courses" to a system that deals with "virtual communities". A virtual community is a highy generalized communication space. In such way, a course given by a professor, a conference, the group of students working on their thesis under the supervision of the same advisor and a group of students collaborating on a project are all instances of the idea of virtual community. A virtual community can be supported at various levels by mobile technologies. LIS, in our definition, become computerized tools that give various kind of services to virtual communities. Such services can be adapted to the special needs of a given community. One research aspect of the present project is therefore linked to virtual communities and info-mobility related to learning: we intend study and experiment how activities of an e-learning portal can be integrated with the emerging mobile technologies. The research group will use an already existing community-oriented e-learning portal that has been in use for some time to integrate and test mobile technology and related methodologies.

Moreover, thanks to the bookmark sharing and recommendation facility, InLinx contributes to human collaborative works: it supports group collaboration among people involved in a work process, independently of time and space distance, and learns from positive and negative experience in group practice.

In its first version, InLinx has been designed as a tool to be used within a group of people sharing common interests or working domain. In origin, it was thought for a researcher group: researchers increasingly choose the Web as primary source where finding resources inheriting their research context. Typically, researchers need to be updated about publications of new papers in their field of interest (see InLinx paper recommendation tool) and they also need to share the most interesting resources with other individuals of the group who are interested in the same domain (see InLinx recommendation tool).

But InLinx can find application in any other context in which the group collaboration is a requisite, like a Web-based learning system [15].

3. Evaluating mobile learning settings

The experience from years of development and use, the advance of technology, and the development of authoring tools for questions and tests has resulted in a sophisticated, computer based assessment system. However, there is still a lot of room for further development. Some of the current ideas for development are discussed in the remainder of this paragraph. In line with many writers in the field of assessment, we distinguish three types of assessment:

- diagnostic assessment; it provides an indicator of a learner's aptitude for a programme of study and identifies possible learning problems;
- formative assessment; it is designed to provide learners with feedback on progress and informs development but does not contribute to the overall assessment;
- summative assessment; it provides a measure of achievement or failure made in respect of a learner's performance in relation to the intended learning outcomes of the programme of study.

The most common distinction in the literature is that made between formative assessment and summative assessment. A formative computer-based test is described as one where the results of the test do not contribute to a student's final grades. Instead, the student's scores are used to assist in improving the student's learning, often by identifying weaknesses in the student's knowledge and understanding of a given area or by helping them to identify and correct misconceptions. In a similar way, lecturers can also make use of the results obtained to help them improve their teaching by identifying areas that students have found difficult to understand. Nonetheless, in many assessment activities the difference is not so evident.

A primary aim of assessment is provide the necessary information to improve future educational experiences because it provides feedback on whether the course and learning objectives have been achieved to satisfactory level. Yet, it is important that the assessment data be accurate and relevant to effectively make informed decisions about the curriculum. [16]. As just introduced in the introduction, formative assessment can also be used to help bridge the gap between assessment and learning. This may be achieved particularly where assessment strategies are combined with useful feedback, and integrated within the learning process [17].

This feedback need not be limited to correct/incorrect responses, but can include detailed textual feedback about answers and the topic area of the question. Formative assessment can assist in consolidation of learning, and in identifying weaknesses in assumed understanding. We think that it would be helpful to be able to deliver the same questions in a number of modes. For example, help mode, exercise and exam, with the test author being able to configure this to their own requirements. The help mode supports students when they start out on their learning; accordingly, the questions are delivered with maximum feedback including hints, visible marking on screen and the chance to reveal a correct answer. Exercise mode restricts the help to just visible ticks and crosses on screen for right and wrong responses. Finally, exam mode presents questions with no option for revealing answers and no ticks/crosses appearing.

Our summative strategy consists of two phases: the former to find the approximate student level, the latter to give the student the right mark using a set of questions customized on his capabilities. The preliminary examination contains for every subject two or more questions for each difficulty level. The score obtained by the student in the first test is used to choose questions to propose in the second test. Using this technique we can build a test which is not redundant (due to the adaptively) and the same firs test set for every student, so we can get data on the quality of the items. Diagnostic assessment is quite similar. In particular, the two-session strategy is the same. The main difference is that it is taken before starting a course, to decide what kind of resources will be used. In this case, the system knows nothing about the student's knowledge; it also records the scores of every answer, so the system can use them when it needs to explain a topic already scored.

When an exam session is completed, we will have a score for every candidate and for every question. To obtain a human-understandable mark we used a function depending on two parameters α and p. We used this function in a large number of real cases and the experimental data showed that the choice of α is important to obtain well-distributed marks. This value can be adjusted after the test correction, in response to the candidate's answers. Moreover, useless items may be discovered. The value p is used to give full marks.

To compose tests easily from a set of items and correct them, the system uses normalized questions and manages the item weighting: when an author creates a course, he sets weights that will influence the automatic item selection and the scoring algorithms. Some of the available forms of assessment strategies included in the proposed system are:

- true/false,
- multiple-response question; it is defined as a question in which the candidate is required to select two or more correct answers from a list of options. Both the number of correct answers and the number of options may vary. We consider the following three principle modes: i) constrained selection: the student is forced to make a prescribed number of selections, usually the same as the number of correct answers; ii) partially constrained selection: the student may make any number of selections up to the number of correct answers; iii) unconstrained selection: the candidate may make any number of selections up to the maximum number of options,
- extended matching item and drag and drop question types share the same process of selection. In either case the student is required to select a number of items from a list then enter or move them to their correct positions. Thus the candidate must make two selections - which item and where to put it. The scoring simplest form considers a positive score allocated for each item correctly positioned,
- image hot spot,

- code writing.

The process of assessment involves gathering information from a variety of sources to develop a rich and meaningful understanding of student learning. Modern computer assisted assessment packages are capable of storing and analysing vast amounts of information on student learning. With appropriate analysis this data can be used to identify the strengths and weaknesses of individual students and match these to learning resources that meet their needs.

4. Agent-based Information Management

Perhaps the most general way in which the term agent is used is to denote a software-based computer system that enjoys the following properties: autonomy (agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state), social ability (agents interact with other agents/ humans via some kind of agent-communication language), reactivity (agents perceive their environment, and respond in a timely fashion to changes that occur in it), pro-activeness (agents do not simply act in response to their environment, but they are able to exhibit goal-directed behaviour by taking the initiative) [17].

There are many possible applications of software agents. The literature identifies application areas where agent technology is, or will be, used, for example, systems and network management, mobile access/management, mail and messaging, information access management, electronic commerce, and so on. For the objectives of the presented paper, we consider information access and management, where software agents should help users not only with search and filtering, but also with categorization, prioritization, selective dissemination, annotation and (collaborative) sharing of information and documents.

So, if the objective is to build a personal assistant who is collaborating with the user in the same work environment, then, we could introduce the interface agents metaphor, that is “computer programs that employ artificial intelligence techniques in order to provide assistance to a user dealing with a particular application” [18]. Moreover, when the agent should have access to at least one, and potentially many information sources, and should be able to collate and manipulate information obtained from these sources in order to answer queries posed by users and other information agents, then we introduce the information agent metaphor [19], [20], [21].

The information sources may be of many types, including, for example, traditional databases as well as other information agents. Finding a solution to a query might involve an agent accessing information sources over a network. A number of studies have been made on information agents, including a theoretical study of how agents are able to incorporate information from different sources [22], [23], as well a prototype system called IRA (Information Retrieval Agent) that is able to search for loosely specified articles from a range of document repositories [24]. Another important system in this area is called Carnot [25], which allows pre-existing and heterogeneous database systems to work together to answer queries that are outside the scope of any of the individual databases.

Moreover, intelligent information agent should exhibit the two following main features:

- cooperation: is the agent able to cooperate with each other for the execution of their tasks? Consider, for example, service brokering, matchmaking, negotiation, collaborative (social) filtering and the application of stemming techniques from the domain of human-agent interaction
- adaptation: is the agent able to adapt themselves to changes in networks and information environments? Consider, for examples, learning personal assistants on the Web.

Next, we introduce how InLinx intends to gather different agent-based modules helping the user to classify domain specific information found in the Web and saved as bookmarks, to recommend these documents to other users with similar interests and to periodically notify new documents potentially interesting, and provides immediate portability and visibility from different user locations, allowing to access the personal bookmark repository just using a web browser through the Learning Management System pages. For each user the system manages a specific user agent.

5. E-learning recommender

An ”e-learning recommender” is a recommendation system that would recommend a learning source to a learner based on his profile, and based on tasks made by other similar learners. The similarity of the learners could be established using user profiles, or could be based on common previous access patterns. In principle, there are two major parts in the design of such a system: a ”learning” module that learns from past access patterns and infers an individual or common access model; and an ”advising” module that applies the learned model at given times to recommend sources. There are many ways to implement this process, such as data clustering, association rule mining, or collaborative filtering, etc [26].

Designing applications for supporting the user on accessing Web information sources is one of the current challenges for the Artificial Intelligence community. As just introduced in the previous paragraph, agent-based solutions represent a natural way of facing this problem, since the above requirements lead to software systems that

autonomously react to user actions and continuously learn, from his behaviour. In particular, dealing with open and dynamic environments requires systems based on multi-agent systems technologies. By combining appropriately agents working cooperatively over space and time to solve a variety of complex problems, that are beyond their individual capabilities, multi-agent systems (MAS) [27] are an important paradigm for building complex information systems, especially cooperative ones, that explicitly and systematically deal with aspects of cooperation and change.

In this paper we propose to introduce InLinx, a multi-agent Web-based hybrid recommender system that provides a on-line bookmarking service in our m-learning architecture. InLinx combines content analysis and the development of virtual clusters of users and of information sources that provides facilities to use the huge amount of digital information according, for example, to the student's personal requirements and interests. Detailed information about InLinx technical characteristics can be found in [15].

The module includes a process of classification and recommendation feedback, in which the user agent learns from the student and adapts itself to the changes in user's interest; this gives the agent the chance to be more accurate in the next classification and recommendation steps. Then, as more students use the system, the more next agent's actions will be accurate.

Our experimental tests produce several reasons to expect that the use of InLinx promotes student information management. First of all, we have tested the classification process. It achieves good results already from the first uses of the system without a formerly training due to used text-learning techniques (stop-list filtering, stemming algorithm, VSM representation and TF-IDF term weighting) and because of fixed category profile never substituted in the student prototype.

Secondly, to evaluate the collaborative recommendation techniques we have considered different initial student profiles. The executed tests have highlighted the several components influencing the choice of recommendation receivers:

- student interest in the category of recommended resource,
- confidence level between students,
- relation between the class prototype of recommended resource and the class prototype of other categories.

The performed experiments have showed that the system respond to the "gray sheep problem" common in a pure collaborative recommendation system, that is, also a student with dissimilar interests respect to other students will be able to receive recommendation.

Moreover, we can consider that in the used test environment each classification produces about two recommendations, showing the importance of the collaborative component of the system.

Finally, to evaluate the content-based recommendation techniques we have considered the knowledge needs of a student surfing the Web to find detailed information about a specific subject. For example, we have considered several issues of on line journals from the web site of the Kluwer OnLine (http://www.kluweronline.com). Our classification algorithm executes ad hoc classification respect to student prototypes, to consider that they can dynamically change over time. So, it is possible that the same document is proposed in two different category for two different students. We have tested InLinx using some issues of "Data Mining & Knowledge Discovery" journal when students have already saved their bookmarks and the system has updated prototypes and student profiles.

Currently, we are working in order to improve the flexibility of InLinx (both in a functional aspect and a structural one, adopting solutions for user modeling capable of capturing not only structural but also semantics information) so that the system could be suitable for an open environment composed by heterogeneous users with miscellaneous interests.

On the system facet, InLinx responds to the request of widely accessible information services, available both to developers and users, and to the ubiquitous computing and communication challenge.

In fact, traditional browser bookmarks lack of immediate portability and visibility from different user locations. InLinx allows to access to personal bookmark's repository from anywhere in every moment, without any software installation. You only need an Internet access point, being a PC as well a mobile device. So, access to your personal and shared data becomes independently of the platform on which the system is executing.

Conclusion

In this paper we present the general idea that a Learning Management System is much more than a system used in educational contexts to let users interact or exchange material. We believe that a LMS is a base from where a lot of extensions could be added in order to fulfill the complex needs of a University institution. We have first extended the Learning Management System at our disposal to mobile technologies, allowing users to interact with the systems and its users using mobile devices like PDAs, cellular phones etc. This extension arises the problem of new learning models that we must deepen in order to understand if the media changes the way we improve our knowledge learning from a computer. Another extension of a LMS we present in this paper regards the integration of a multi-agent recommendation system, which aim is to collect data about the users' behavior and preferences and then suggest them educational resources. InLink has an hybrid approach, it is able to effectively filter relevant resources from a

wide heterogeneous environment like the Web, taking advantages of the shared interests among users without losing the benefits provided by content analysis.

References

[1] Waycott J.: An Investigation into the Use of Mobile Computing Devices as Tools for Supporting Learning and Workplace Activities , 5th Human Centred Technology Postgraduate Workshop (HCT-2001), Brighton, UK, September 2001, available online at http://www.cogs.susx.ac.uk/lab/hct/hctw2001/papers/waycott.pdf

[2] Roibás A.C., Sánchez I.A.: Design scenarios for m-learning, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 53-56), Birmingham, UK, June 2002

[3] Rogers T.: Mobile Technologies for Informal Learning – a Theoretical Review of the Literature, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 19-20), Birmingham, UK, June 2002

[4] Dvorak J. D., Burchanan K.: Using Technology to Create and Enhance Collaborative Learning, Proc. of 14th World Conference on Educational Multimedia, Hypermedia and Telecommunications (ED-MEDIA 2002) , Denver, CO, USA, June 2002

[5] Kukulska-Hulme A.: Cognitive, Ergonomic and Affective Aspects of PDA Use for Learning, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 32-33), Birmingham, UK, June 2002

[6] Waycott J., Scanlon E., Jones A.: Evaluating the Use of PDAs as Learning and Workplace Tools: An Activity Theory Perspective, Proceedings of the European Workshop on Mobile and Contextual Learning, (p. 34-35), Birmingham, UK, June 2002

[7] Keegan D.: The future of learning: From eLearning to mLearning, available online at http://learning.ericsson.net/leonardo/thebook/book.html

[8] Casadei G., Magnani M., Assessment strategies of an intelligent learning management system, accepted for publication in "International Conference on Simulation and Multimedia in Engineering Education, 2003" conference proceedings

[9] A'herran A., Integrating a course delivery platform with information, student management and administrative systems, in Proc. EDMedia 2001, Tampere, Finland, June 25-30 2001

[10] Hall B, Learning Management Systems. How to Chose the Right System for your Organisation, Brandon Hall, 2001

[11] McMahon M., Luca J, Courseware Management Tools and Customised Web Pages: Rationale, Comparisons and Evaluation, Proc. EDMedia 2001, Tampere, Finland, June 25-30 2001

[12] Hanna, D. E., Glowacki-Dudka, M. & Conceicao-Runlee, C. (2000). 147 Practical tips for teaching online groups: Essentials of Web-based education. Madison, WI: Atwood Publishing.

[13] Aggarwal, A. Web-based learning and teaching technologies: Opportunities and challenges.. Hershey, PA: Idea Group Publishing 2000.

[14] Colazzo L., Molinari A. (2002) From Learning Management Systems To Learning Information Systems: One Possible Evolution Of E-Learning, in Proc. Communications, Internet and Information Technology (CIIT) Conference, St. Thomas, USA – November 18-20, 2002

[15] C. Bighini, A. Carbonaro, G. Casadei (2003) "InLinx for Document Classification, Sharing and Recommendation", 3rd IEEE International Conference on Advanced Learning Technologies, ICALT'03, Greece

[16] Huba, M.E. & Freed, J. E. (2000). Learner-centered assessment on college campuses. Shifting the focus from teaching to learning. Needham Heights, MA: Allyn & Bacon.

[17] M. Wooldridge, N. Jennings (1995), Intelligent Agents: Theory and Practice, Knowledge Engineering Review Volume 10 No 2, June 1995. Cambridge University Press

[18] P. Maes, (1994b). Social Interface Agents: Acquiring Competence by Learning from Users and Other Agents. In Etzioni, O., editor, Software Agents - Papers from the 1994 Spring Symposium (Technical Report SS-94-03), pages 71-78. AAAI Press.

[19] M. Klusch (2000), Information Agent Technology for the Internet: A Survey. Journal Data & Knowledge Engineering, Elsevier Science, 36(3)

[20] M. Klusch (ed.) (2001) Special Issue on Intelligent Information Agents: Theory and Applications, Intelligent Cooperative Information Systems, vol. 10(1&2)

[21] Delgado, J., 2000, "Agent-based Information Filtering and Recommender Systems on the Internet", PhD Thesis, Nagoya Institute of Technology

[22] T. R. Gruber, (1991). The Role of Common Ontology in Achieving Sharable, Reusable Knowledge Bases. In Fikes, R. and Sandewall, E., editors, Proceedings of Knowledge Representation and Reasoning (KR&R-91). Morgan Kaufmann Publishers: San Mateo, CA.

[23] A. Y.Levy, Y.Sagiv, and D. Srivastava, (1994). Towards Efficient Information Gathering Agents. In Etzioni, O., editor, Software Agents - Papers from the 1994 Spring Symposium (Technical Report SS-94-03), pages 64-70. AAAI Press

[24] E. M. Voorhees, (1994). Software Agents for Information Retrieval. In Etzioni, O., editor, Software Agents - Papers from the 1994 Spring Symposium (Technical Report SS-94-03), pages 126-129. AAAI Press.

[25] M. N. Huhns, N. Jacobs, T. Ksiezyk,, W. M. Shen, M. P. Singh and P. E. Cannata, (1992). Integrating Enterprise Information Models in Carnot. In Proceedings of the International Conference on Intelligent and Cooperative Information Systems, pages 32-42, Rotterdam, The Netherlands

Dalziel, J. R., & Gazzard, S. (1999b). Beyond Traditional Use of Multiple Choice Questions: Teaching and Learning with WebMCQ Interactive Questions and Workgroups. Open, Flexible and Distance Learning: Challenges of the New Millennium - Collected papers from the 14th Biennial Forum of the Open and Distance Learning Association of Australia, 93-96. Geelong: Deakin University.

[26] O. R. Zaine (2002), “Building a Recommender Agent for e-Learning Systems”, Proc. of Int. Conf. on Computers in Education (ICCE’02)].
[27] Huhns M. N., Singh M. P. (eds): Readings in Agents. Morgan Kaufmann San Francisco (1997)