Computational Intelligence in adaptive and accessible learning environments

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Abstract
Computational intelligence techniques can be used to provide support for the accessibility requirements of adaptive learning management systems (aLMS). To cope with the needs for all and support the required functional diversity features, an aLMS should modify the user interface and the content according to the psycho-pedagogical procedures, the context in which the user is accessing the information and the device used for that purpose. The information for these adaptations can be mined from data stored in the aLMS from the users’ interactions in the course. In this paper we focus on an Accessible and Adaptive Module (A2M) which is based on a multi-agent architecture that builds the user models from data mining techniques applied to the learners’ interactions data. The usage of open software solutions and standard-based service architectures facilitates the reusability of models and architectures.

Keywords
Artificial Intelligence, Computational intelligence, Adaptive systems, Recommending systems, Multi-Agent Systems, Data Mining, Machine learning, Educational standards, Metadata, Learning design, User modelling, Accessibility, Open source.

1. Introduction
Many areas have applied artificial intelligence (AI) techniques, such as data mining and intelligent systems to enrich their traditional functionality. At aDeNu group, we focus our research mainly on educational applications, where we aim to improve the students’ learning process in learning management systems (LMS) by providing adapted responses to the learners’ needs. We address the problem of effective adaptive learning by providing personalized e-learning based on different types of adaptations. We rely on the combination of desing and runtime adaptations [1] where we use the design specifications to frame the discovery of the users’ needs and features by data mining learners’ interactions. We apply data mining techniques to address critical issues, mainly to: 1) guide student learning effort, 2) develop and refine student models, 3) improve teaching support and 4) predict student performance and behaviour. Raw data is obtained from database queries and server logging, which record learners’ interactions in the aLMS. These data is later used as input for the machine learning techniques (i.e. naïve-bayes, decision tree and nearest neighbour, …) to learn high level indicators of the students performance.

To support this approach, first at aLFanet project (IST-2001-33288), we developed an architecture that use open communication protocols and provides adaptive educational services to learners according to the individual and collaborative user’s needs by combining design time and run time adaptations and making a pervasive use of educational standards (IMS-CP, IMS-LD, IMS-QTI, IMS-LIP, IMS-MD) along the full life cycle of eLearning. In particular, advanced pedagogical models, based on the concept of active and adaptive learning, can be specified by the authors of the course at design time to support user’s interactions at run time.
However, as not everything can be foreseen in the design process, there is a need for continuous monitoring the learning behaviour to provide dynamic personalized guidance to learners [2]. Nevertheless, aLFanet has two significant limitations. On the one hand, the architecture itself (see Fig. 1 and [3] for details), whose performance is far away to be run in a production environment and therefore, enough users’ interactions data for the data mining process cannot be gathered. The reason for this limitation is twofold. First, at the time of the project there was no open source architecture that could be taken as a starting point and second, educational standards support did not exist either. Thus, the architecture and most of the components had to be built from scratch in the project. On the other hand, accessibility requirements to remove access barriers of people with disabilities were not considered. Accessibility is an area in which adaptation can play a major role to satisfy very demanding needs for learners, especially in the Life Long Learning (LLL) paradigm. In fact, current reports and initiatives, such as [4] promote a personalized learning approach centered on the user, where e-learning products and methods are to take into account individual needs. Hence, there is a strong need for modelling users’ needs and preferences form mining their interactions.

In order to tackle with the shortcomings of aLFanet, the current research efforts of aDeNu group are led towards integrating accessibility support into the full life cycle of eLearning and using existing open standard-based architectures that facilitate the data gathering and processing. Three research works are in progress to remove access barriers in eLearning. Their objectives are diverse but complementary. In FAA project (PGIDIT-05-SIN-011-E) we have selected an open source software for supporting e-learning communities called dotLRN for its capabilities for adaptivity, reusability and accessibility [5, 6]. In particular, we are working in collaboration with OpenACS/dotLRN consortium to improve the platform in order to provide an inclusive system based on standards, which personalizes and adapts e-learning contents and activities, pedagogical models and learners’ interactions to satisfy the particular needs and preferences of learners with functional diversity [7]. Moreover, we are working on providing support for specifying the learners’ interaction preferences with IMS Accessibility Learner Information Profile (IMS-AccLIP) and for modelling the capabilities of the devices used by the learners to access the aLMS with Composite Capabilities Preference Profiles (CC/PP).

In EU4ALL project (IST-2005-034778) we are developing a flexible, open, standard-based service-oriented architecture to provide accessible services for people with functional diversity following the universal design principles and supporting the LLL paradigm [8]. This architecture is based on OpenACS, the toolkit for building scalable, community-oriented web applications upon which dotLRN is developed. OpenACS is a collection of pre-built applications and services that can be used to build services and applications through a modular architecture. The reasons for selecting this architecture are 1) the security and robustness, 2) the flexibility for new developments and 3) the web services support [9]. Moreover, as it can be seen in Fig. 1, about 80% of aLFanet architecture is currently supported by OpenACS in terms of components and educational standards, but with high reliability and performance parameters. Finally, although EU4ALL results are to be validated in large-scale settings, a Market Validation is being performed in ALPE project (eTen-2005-029328) with 300 learners with disabilities that lack some basic skills. This project started on January 2007 and initial relevant results are expected by June 2007.

This research work is framed within the aforementioned projects and open source frameworks (OpenACS/dotLRN). The following section describes the Adaptation Module (AM), the machine learning multi-agent architecture to provide the dynamic support for the users designed and developed for aLFanet project [10] to build the user models from the learner interactions in the LMS. Next, considerations coming from the accessibility based projects which are taken into account in the Accessible and Adaptive Module (A2M) to remove the access barriers for disabled learners are presented. Finally discussion and future works section is provided.
2. The aLFanet experience

In order to generate dynamic contextual recommendations during the course execution, we have designed and implemented the Adaptation Module (AM) in aLFanet Service layer [3]. This module is in charge of generating these recommendations based on the learners’ characteristics (managed in IMS Learner Information Profile – IMS LIP), learners outcomes from the course (IMS Question and Test Interoperability – IMS QTI), the contents metadata (IMS Metadata – IMS MD), the course learning desing (IMS Learning Desing – IMS LD) and the course structure (IMS Content Packaging – IMS CP). These characteristics combine individual needs based on user’s personal information (e.g. learning styles, objectives interests, lack of knowledge, learning preferences, etc.) and collaborative needs focus on users’ relationships among them (e.g. contact with students with similar characteristics, access to relevant comments or materials sent by other learners, collaborate with a particular workgroup, etc). This contextual adapted responses to the learners are based on finding similar users according to i) learning styles, ii) knowledge level at the beginning of the course, iii) interest level for each course objective, iv) learning path followed, v) implicit collaboration interactions, vii) opinions on learning items such as comments, ratings, categories, links between learning objects, and viii) assessment results from the objectives worked. Details on how implicit collaboration is managed are provided in [11].

The AM includes the configuration of adaptation tasks and the delivery of recommendations during run-time. It is built upon Java Agent DEvelopment Framework (JADE) an open source framework for peer-to-peer agent based applications. The communication with aLFanet architecture (i.e. the Dispatcher) is done via a JAXM (Java API for XML Messaging) interface that implements SOAP protocol. The system includes JADE agents and use FIPA-ACL as communication language. The following figure shows the multi-agent architecture of the AM and a snapshot of the agents’ communication while running the multi-agent system. The AM consists of a two level hierarchy of multi-agent architectures that works autonomously to solve...
the adaptation tasks required. The lower level hierarchy is built inside a Modelling subsystem and deals with learning the attributes of the models. WEKA (a data mining with open source machine learning software in Java) algorithms provide the intelligence to these agents. In particular, naïve-bayes, decision tree and nearest neighbour algorithms are applied.

Moreover, this multi-agent system is prepared 1) to include meta-learning techniques, where each Classifiers Agent learns a classifier with different algorithms or with different data sets, 2) to combine their responses with the different existing techniques (e.g. voting, stacked generalization, cascading) with the Modelling Agents once the classifiers are learnt, 3) to select the responses of one of the Modelling Agents, or a combination of them with the Advisor Agent, who behave as a referee that evaluates the competence of each of the Modelling agents with respect to the attribute to be learnt, and 4) to control when to train each of the agents with the Trainer Agent. This approach has been successfully applied and evaluated in other research works, but due to the lack of time between the end users evaluations and the finalization of aLFanet project, there was no time to experiment with these combined algorithms.

Figure 2. aLFanet Adaptation Module architecture and snapshot of the agents collaboration.

In turn, the high level hierarchy deals with providing the recommendations (or adapted responses) to the users. When the learner interacts with aLFanet, the Dispatcher asks the Adaptation Module (i.e. the Coordinator Agent) for a recommendation to give to this particular learner. To generate a recommendation, the AM needs to know: 1) the current status of the learner, including a snapshot of the situation of the learner in the courses and the context of the learner obtained from the Dispatcher in the request, 2) the historic of learner’s interactions obtained from the Tracker, 3) statistical/generic information about learners progress in the course and 4) access to the information stored in the Models. The Coordinator Agent, in turn, asks the different Recommendation agents if they have some recommendation to give. The Recommendation Agents need to know the user model of this particular learner to produce the corresponding recommendation. Thus, the Model agents are asked. Model Agents update their knowledge from the learners’ interactions. Some
attributes of the model are directly the data gathered by the system and stored in the Data layer, but most of the attributes need to be obtained dynamically with data mining techniques in the Modelling subsystem, basically the machine learning algorithms described above. Moreover, a Configuration Submodule is used to allow the user define new classification tasks to learn new attributes from learners’ interactions, to configure the different agents of the system and to configure the adaptation tasks.

3. Extending the data mining infrastructure to provide adaptation tasks to support all

When learners have disabilities that affect their interaction with a computer environment, not only the different interests and sets of needs have to be taken into account, but also the preferred access strategy for each user. More specifically, the accessibility requirements for learners with special needs have implications in all the modules that make up the architecture of an adaptive learning management system. Apart from the guidelines for the user interface (WAI-WCAG), the user model has to deal with the interaction features of the learners, the pedagogical model has to consider the appropriate learning strategies for each type of disability and the domain model has to include a variety of learning materials suitable for the different interaction needs of the learners. All these issues affect the data to be gathered and processed.

Adaptations to disabled users’ interactions have to put a big emphasis on properly modifying the user interface and the content according to the particular disability of each user, the pedagogical and psychological procedures, the context in which the user is accessing the information and the device used for that purpose. For instance, in case of visual impaired users, the size of the components of the screen should change (they may not see small objects), different colour pairs should be used (some users may not see white on black but others is the best combination), the information should appear only on certain parts of the screen (users may have vision just in the centre of the object they look at), different and customised keyboard shortcuts should be available (totally blind users cannot use a mouse). In respect to auditive impaired users, the customisation should address selecting the appropriate range of frequencies where the user has audition, or translating auditive alerts to visual messages, etc.

To cope with the needs for all we are now working on an Accessible and Adaptive Module (A2M). This module follows the same approach as aLFanet AM, including a two level hierarchy of multi-agent architectures that work autonomously to solve the adaptation tasks. The high level consists of a set of agents that interact to select the appropriate contents and services and adjust the user interface so that the learners’ needs and preferences are satisfied. In turn, the low level is used to learn the attributes of the models from the interaction data. An hybrid approach that combines knowledge-based methods and machine learning techniques is being considered here. To follow the open source approach, CMU-CL is the candidate to implement open THEO Agents in Lisp to build the truth maintenance system [12].

Moreover, the A2M is being integrated in OpenACS/dotLRN framework instead of in aLFanet J2EE architecture due to the advantages discussed in section 1. The communication is done through web services technologies using the Xo-SOAP support provided by OpenACS. This usage of web services for device modelling has been successfully applied in other works [13] to allow the semantic interoperability of the different data available. Moreover, OpenACS/dotLRN includes a user tracking package that produces high level interaction information coming from data stored in the data base and traces printed in the server logs.

Content provision is focused on users’ needs and based on specifications and standards. Since automated responses to the accessibility needs of individual students are to be made, the A2M requires information about each individual (including records on their needs, preferences, learning styles, etc.) and the current context. To model the user in terms of their access requirements existing specifications and standards are being considered to facilitate the definition of these models, such as IMS AccessForAll, the ‘Individualised Adaptability and Accessibility for Learning, Education and Training’ (ISO IEC JTC1 SC36) and CC/PP. The first two address accessibility requirements in learning
specifications (i.e. learning profiles and content metadata), while CC/PP facilitates the device modelling (e.g. X-SHAAD [14]).

To summarize, adapting the service delivery according to the user disabilities, interests and needs requires 1) to define the interaction preferences, 2) to learn user profiles from interaction data by combining the different needs and considering their evolution over time, 3) to take devices and context-awareness into account, 4) to support pedagogical scenario at runtime via recommending systems, 5) to support psychopedagogical guidelines and 6) to report on the interactions to adjust the service. Educational data mining techniques that process raw data and convert it into useful information support these requirements.

4. Discussion and Future works

This research is framed within an open and standard-based approach focused on accessible services for all which makes a pervasive use of educational standards. In particular, a multi-agent architecture to support the adaptive behaviour to the learning and special needs is built, following a similar architecture as the previous work in aLFanet [10]. Accessibility is not something that can be plugged in a particular content or service, but it requires considering the full life cycle of eLearning. This is of major importance when adaptation is to be provided taken into account accessibility requirements. This implies that new data has to be gathered to model the interaction preferences.

In this paper we have presented an open architecture based on educational standards (IMS family) where data mining tools and techniques are fully integrated with the IMS specifications. This approach improves existing tutoring systems in the sense that provides support for educational specifications and standards and uses the learning management systems services (e.g. forums, file storage, calendar, learning units, course tracking, …). We have introduced the research problem in section 1 and positioned ourselves relative to the prior work in aLFanet in section 2. In the third section we have defined our approach which mainly focuses on providing answers for the following open questions: 1) what new discoveries does data mining enable?, 2) what techniques are especially useful for data mining?, 3) how can we integrate data mining and existing educational theories?, 4) how can data mining improve teacher support?, 5) how can data mining build better student models and 6) how can data mining dynamically alter instruction more effectively?

This approach fits in the current needs and challenges in Higher Education settings. On the one hand, the adaptivity, reusability and accessibility issues that are of major importance for the lifelong learning paradigm. On the other hand, the usage of open software solutions and standard-based service architectures to support application integration. Moreover, the collaborative filtering approach for the recommendations is similar to the existing recommending systems available on the web. These systems predict the future interests by analysing the users’ behaviour, opinions and evaluations. They benefit from the social networks and other charateristics on the Web 2.0. The pioneer was Amazon, but other business follow the same philosophy, such as NetFlix, Ask.Com, Yahoo Launch or MyStrands.

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References

integration of Information and Communication Technologies (ICT) in education and training systems in Europe'


