MAGADI: a Blended-Learning Framework for Overall Learning

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Abstract: The MAGADI framework results from merging characteristics of three current technologies: adaptive intelligent systems, authoring tools and LMS technologies. Its main aim is to be the technological component of a b-learning environment. As a result it allows for the flow of information and synergies between on-line and off-line environments. This paper describes the general agent-based architecture of MAGADI and some results of the prototype-testing.

Keywords: blended-learning, dynamic adaptation, agents

Introduction

Blended-learning (B-Learning) is a recently-coined term which describes those learning scenarios that combine face-to-face (F2F) and computer-mediated instruction [1]. This approach has been proposed in order to improve the learning process by means of tight integration between traditional classrooms and on-line learning environments [2]. The blend of such learning or teaching styles must be developed in a thoughtful way so that “F2F oral communication and online written communication are optimally integrated such that the strengths of each are blended into a unique learning experience congruent with the context and intended learning experience” [3].

MAGADI [4] is our proposal for a technological solution for B-Learning with real integration of on-line and off-line activities. It is a domain-independent, open and adaptive learning platform whose adaptation style can be modified at any time by the teacher. This paper describes the general agent-based structure of MAGADI and its student-orientated functionalities. The first section outlines MAGADI, then a more in-depth description of its knowledge representation schema follows. After that, the student workspace is presented. Finally the system’s first prototype-testing evaluation, some related work, and conclusions are presented.

1. Blended Learning and MAGADI

Most current learning experiences, such as those related to higher education, usually tend to combine computer technologies and classic F2F oral communication. However, as teachers have experienced, the simple use of computer technologies does not assure any improvement in the user’s learning. Teachers and students need on-line tools that provide adaptation and promote a real synergy between both learning styles.

The adaptivity of a technological component for a B-Learning solution must allow information to flow between the on-line and off-line environments. That is, the results
of the on-line activities are to be taken into account by the off-line activities and vice versa [5]. In this way, the educational experience, taken as a whole, profits from the advantages of both, whereas each one solves the drawbacks of the other. To obtain these results, adaptivity in the on-line component must not only be based on student-system interactions (as is the case in classical ITS or AWBES). It is also imperative that the adaptivity style be both flexible, based on criteria specified just for the current session (i.e. Just-in-time adaptation), and “anytime modifiable” by the teacher in order to consider F2F interactions as well. Moreover, a global approach for current education trends demands learning environments be able to integrate the inter-related representation of several domains. In this type of environment, teacher presence is essential as it “establishes the curriculum, approaches, and methods; it also moderates, guides, and focuses discourse and tasks” [3].

From a teacher’s perspective, we can set three goals: (A) teachers can immediately take into account the results of the student’s on-line activities to configure their teaching plans (Just-in-time teaching [6]); (B) the on-line system considers the student’s new learning status, not only from automatic inferences about student-system interactions, but also from teachers in F2F interaction [5]; and (C) the system adapts itself to the student at the beginning of each session, taking into account a set of possibly variable adaptation criteria defined by the teacher in a Just-in-time way. Three additional goals can be added by considering the student’s perspective when she is involved in an overall learning process which includes several courses and teachers. They are: (D) to provide a global environment which is able to integrate all the courses the student is enrolled in, in order to (E) help her to learn organising skills in her overall learning experience by (F) always showing the domain subset matching her own acquired knowledge.

To answer these needs, MAGADI allows an interleaving of uses, in the sense that authoring and learning can happen at the same time and thus influence one another. In order to do that, MAGADI is organised around three related workspaces. It dedicates an agent-based [7, 8] workspace for each target user—teacher, student, author—and provides a common shared background composed of several knowledge bases. These support knowledge and information flow among the different workspaces and contain both domain-dependent and independent knowledge about the areas represented.

### 2. Knowledge Representation in MAGADI

Adaptive on-line educational systems are supported by three main categories of knowledge: student, subject domain, and pedagogical. MAGADI shares this categorisation and organises it according to its direct predecessors INTZIRI and DETECTIVE [9]. It organises the related information by means of several stand-alone database servers and a multi-layer ontology which provides the underlying conceptual schema; all of them taken together provide a data structure appropriate for information description and exchange. Moreover, the CLAI instruction theory model is integrated, making MAGADI a theory-aware system [10].

The database servers allow anytime access and modification by the teacher, MAGADI or any other B-Learning component. In any case, the information changes are instantly considered by MAGADI.

**Domain and Course General Knowledge.** MAGADI stores information about several *domains* together with the interrelationships among their components; each domain can
also be structured into several subjects. In addition, the course adds a temporal dimension (academic year) to the subject description; thus, the course introduces a schedule or chronological plan that is defined and modified by teachers whenever needed (goal A). This overall layered approach allows us to define curricula dependences and calendar information that favour the blended-learning approach. We have defined a general and distributed domain repository for MAGADI, supported by both a database and a meta-ontology which articulate the set of basic learning units, the instructional objectives (skills or competencies) to be developed by the student and the inter-element pedagogical and structural relationships. Figure 1 shows a fragment of the domain and course meta-ontology as defined in PROTÉGÉ.

Student Knowledge. In order for teachers to influence the system and vice versa, MAGADI’s adaptive behaviour requires that the students’ knowledge and skills in several subject domains be stored, and it allows teachers to include their findings derived from F2F interactions (goal C). Student knowledge is represented by a generalised overlay model; it comprises the whole set of subjects being learned by students in such a way that each subject includes subject-specific information (i.e. presented elements, completed activities, basic learning units acquired, and so forth) as well as inter-subject issues. The student database also includes some domain-independent information such as each subject’s teacher, log interaction files and the students’ own comments. This structure resides in a centralised user modelling server [11-14]. These servers are independent from application systems rather than being part of them, i.e. they are not functionally integrated into the application but communicate with it [13]. Thus, each MAGADI workspace provides a knowledge agent for server interaction capable of generating a view as required for the current educational use.

Pedagogical Knowledge. The pedagogical database stores the knowledge required to configure the student workspace agents and therefore adapt the instructional plan that guides the learning session dispatching [15].

A rule-based planner based on IRIS tutors [15, 16], which integrate a pragmatic cognitive theory of instruction (the CLAI Model), performs the process of building the Instructional Plan, which in turn determines the tutor’s activities. MAGADI provides a configuration stage in the student workspace that allows the underlying adaptation criteria for generating the instructional planner that will guide the student activities to be varied among sessions. This behaviour, together with the possibility of anytime modification of the pedagogical knowledge by the teacher, provides the system with great flexibility and an adaptivity style also based on the results of F2F interaction.

The sets of predefined rules related to each strategy as well as their customisation (for instance: number of attempts for each exercise, whether to take into account the student’s learning style) are stored in the pedagogical database.
3. System Architecture, the Student Workspace

MAGADI is approached as a dynamic system based on a multi-agent architecture, where a set of databases form the integration layer of three user-orientated workspaces. They share the same main agent structure whose basis is taken from the RETSINA [7] framework. Agents are divided into three categories: interface, information (knowledge) agents and task agents. Interface and task agents are specialised for each user type (teacher, student and manager) in order to represent their specific functionalities. Concretely, the basic agent architecture of the student workspace (figure 2) follows the classical module structure of ITS, such as INTZIRI [15].

![Figure 2. Student workspace architecture](image)

A student learning session on MAGADI is usually composed of different session fragments defined by a) the course being studied, b) the contents being worked on, and c) the strategy being used (for instance review, free or guided). To give on-line sessions the Just-in-time property (goal C), each fragment component goes through the Configuration and Dispatching stages, which are shown in figure 3.

![Figure 3. Development of a learning session fragment](image)

First, the Configuration stage establishes the adaptivity criteria and makes up the system’s agent structure; that will conduct the student learning session during the Dispatching stage. Since one of the main MAGADI objectives is to help the student to create her work-plan (goal E), a recommendation layer has been included in the system architecture to help the student to choose the course and/or topics required in the configuration stage. The agents’ information exchange is based on a multi-layered ontology [17]. Figure 4 illustrates information flow in the student workspace.

![Figure 4. Information flow in the student workspace](image)

Dispatching Stage. This contains the agents that conduct the student session: a Planner,
generated in the configuration stage, and an Evaluator. The main actions carried out by the Planner Agent are to select which subject material to show next and which pedagogical action to carry out next. This selection process is based on the IRIS [15] rule-based planner, mainly due to its domain-independent approach.

The system evaluation capabilities are provided via the Evaluator agent that links the diagnostic capabilities of DETECTIVE [9]. Again, this system was selected mainly due to its domain-independent evaluation capacity.

**Configuration stage.** Three steps shape the dispatching agent’s structure: a) course selection, b) topic selection and c) strategy selection and parameterisation; they are developed by a set of agents: Strategy Selector, Pedagogical Selector and Content Selector. These agents can either help the student in her decision-making process or decide which content and strategy should be used by the system. All the configuration agents obtain the information from the shared databases. As a direct consequence, this configuration stage allows the on-line activities to take into account not only the results of the previous on-line sessions (with MAGADI or other on-line systems that modify the shared databases) but also the results derived from off-line activities (entered into the database by the teacher). Moreover, MAGADI facilitates progressive authoring, even when the system is being used, in the same way that good teachers change their teaching strategy according to newly emerging parameters, such as bad student results. Next, we describe how the different decision-making processes are developed.

![Figure 5. Some student session screens](image)

Firstly, the student selects a course to study from the ones she is enrolled in. To help the student with her decision-making, a list of courses is offered, which includes comments that advice students. For instance, in the course list in figure 5, the system points out to the student that “for the first course there is an exam coming up whose contents have not been mastered” whereas for the second one a “scheduled teacher suggestion has not yet been carried out”.

At this point, the student is offered her personal schedule, matched with her knowledge (figure 5). This is the start page for any course, and it provides the tools that allow the student to configure her study session. Every element of her schedule is enriched with information about her acquisition level—for instance, whether a given topic or its prerequisites have been learned or not. In the interface illustrated above, the student can choose to work on the topic or its prerequisites in a free or guided style.

The student can also ask the system for the course content. This is represented by means of an adapted hierarchical tree where some topics are not accessible, for instance because its prerequisites are not verified, and the others are marked with the student’s results. Once the topic has been selected, the resulting tree for the free session can be parameterised so that, for example, the student can select to visualise all the topic’s
exercises or only those not yet attempted. Therefore, the system allows different choice granularities, which each student can use as desired at the beginning of a session fragment, giving the student an extra degree of flexibility.

4. System Evaluation

The first prototype-testing stage was developed during the first semester of the 2008-2009 academic year with students from the courses Programming I and Database Management, first and third year Computer Science courses, respectively, at the University of the Basque Country.

A small group of students from Programming I was selected to learn the target topic “Pointers in Ada” via MAGADI only, whereas a control group (16 students) followed traditional F2F classes. Several orthogonal aspects related to students and teachers were tested: a) estimation of difficulty/ease in using the teacher authoring workspace, b) students’ difficulties and c) improvements in learning when using the platform. To this end, the subject teacher (external to the MAGADI development team) created the learning resources for each topic, the content structure, course calendar and student-orientated remarks (authoring workspace). The recommendation remarks created by the teacher for some students in Programming I, together with the general development plans of the other first year subjects—Algebra, Digital System Design, Mathematical Analysis—were used by MAGADI to generate personalised work-plan recommendation remarks for the students. At the end of the process, the same Moodle exam on the target topic (composed of 13 questions) was taken by both groups. We found that the exam marks of the test group were better than those of the control group, as were the deviation in answers; the best mark was in the test group [18].

All the students in Database Management were involved in the second test. Its objective was to check both the suitability of helping personal planning and the utility of free sessions with resources and activities adapted to the student. The semester was divided into theoretical-F2F and practical lectures. All students, used MAGADI to do course-related exercises during practical lectures. On the first day, MAGADI was presented to the students; after that they used it on their own. After each MAGADI session, students answered a survey composed of both open and closed questions, with the aim of identifying student criticisms and perceived advantages of the global system and each of the provided functionalities. At the end of the test, we also compiled the teacher’s impressions of the blended experience.

As expected, 100% of the students found the system helpful for doing their homework. They described the experience as “very interesting for personal study” and “a motivation tool”, “very entertaining and dynamic”, “an interesting tool for evaluating the knowledge acquired and to help the study process”. 80% of students used the functionality of visualizing prerequisites for lectures to prepare for subsequent lectures, and all the students who received teacher suggestions found the idea of suggestions and the system remarks regarding available personal suggestions useful.

The database teacher indicated that after a period of learning how to use MAGADI, the experience was “very enriching and interesting”. The loop between the on-line and off-line/F2F environments created a very pleasant atmosphere for teacher and student interaction. Students felt that the teacher “was interested in their study process” and

\[1\] The student group used in this initial testing stage was too small for statistical validation.
“wanted to help them”, which made the students more receptive and participative.

A common challenge in the b-learning loop is engaging students prior to F2F interactions. In the experiments carried out, we noted that students responded better when they observed teachers adjusting the lectures according to the outcome of their work. Teachers indicated that, initially, the b-learning approach and platform were not easy because they involved changes in their teaching style, but the positive results they received encouraged them to continue.

5. Related Work and Conclusions

The different student and teacher perspectives have allowed us to define six main goals that MAGADI satisfies to a greater or lesser extent (goals A to F in Section 1). They can be used as a basis for comparing MAGADI with some current frameworks.

The student overall learning experience expressed by objectives D to F requires to integrate information from several subjects and also to exploit their inter-relationships. All current trends include this multi-course necessity; examples are the Learning Management Systems mainly adopted by universities [11] (e.g. Moodle [19]); however, they barely adapt to the learners. AHA! [20] includes several adaptive courses in a server; KnowledgeTree [11] and MEDEA [21] allow for the integration of different Web-based Adaptive Educational Systems [22]. However, while these systems allow the student to work with different courses, each of them is treated independently of the others, so the student does not benefit of the possible emergent synergies. For instance, they don’t cover concepts shared by several subjects or provide the student with a calendar compiled from several subject schedules. Therefore, they do not meet goals D, E and F regarding inter-subject relationships and overall student time schedule.

To work with these interactions, the MAGADI’s Student Model resides in a database that can be manipulated from different applications, taking the ideas of user modelling servers [13]. As a result, it can be modified by the teacher to introduce new information by using a set of analytical tools [23]. In this way, teacher goals A and B, which immediately take into account the students’ interactions in planning learning sessions, are considered. Additionally, and like previously mentioned systems, MAGADI adapts itself to the student’s requirements at the beginning of each session (goal C); it also allows different pedagogical strategies to be used for different parts of the same course in the same way that ACCT [24] does. MAGADI can also vary the strategies applied to the same course parts according to current student requirements.

In summary, MAGADI is a Web learning platform founded on the concept of blended-learning in which the two human actors—student and teacher—play a significant role in its adaptation functionalities. Its main characteristics allow support of overall student learning by integrating several domains, their related subjects and a set of multi-level pedagogical features. Its architecture integrates three agent-based user type workspaces, related by means of a common multi-layer ontology and a set of shared databases. The MAGADI adaptation mechanism cohesively integrates the student learning characteristics obtained from both automatic inferences from the e-learning system and those detected in face-to-face interaction during traditional learning sessions. Thus, it dynamically generates tutoring behaviour according to the changing characteristics emerging from each learning session: that is, it provides Just-in-time adaptation to the student’s current learning necessities, determined by her learning history and the teacher’s objectives.

Currently, the prototype is being evaluated. It was tested with students in the
database and programming domains, where it was well received by both students and teachers. The blended approach presented here improves both student learning and teacher satisfaction. After compiling the opinions, some implementation improvements have been made and the evaluation will continue during the next semester.

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References