Adaptive virtual courses development based on multi-agent system approach

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Abstract: The aim of this paper is to present a generic proposal for adaptive virtual courses development based on Artificial Intelligence techniques, in particular Multi-Agent Systems, Artificial Intelligence Planning, and Case-Based Reasoning (CBR). The design and implementation by means of a Pedagogical Multi-Agent System approach and the definition of the framework to specify the adaptation strategy allow us to incorporate several pedagogical and technological approaches, according to the teamwork’s points of view in the concrete implementation and installation. The automatic generation gives a customized virtual course applying one explicit strategy of adaptation that recognizes diverse characteristics of each learner (psychological, psycho-pedagogical, academic path of each student, expressed in terms of Educative Objectives). The model was validated through the experimental platform SICAD (Intelligent System for Adaptive Courses), which is presented at the final section.

Keywords: Adaptive courses, Multi-Agent Systems, AI Planning, Case-Based Reasoning, Adaptation Strategy

1. Introduction

The adaptability of a system may be defined as the capacity of the system to dynamically adapt its behavior to the requirements of the user-system interaction (Duque, 2007).

The expectations, expressed since the decade of 1970, for individualized education supported on Information and Communication Technologies, in which each student is individually recognized; the specific student’s rhythm of learning be respected; different paths towards the proposed educational objective using enriched learning objects and multi-modal activities are provided (Eraut, 1970;
Stolurow, 1970; Alfaro et al., 1998), still represent an unfulfilled objective. Although there has been much promises, about the e-learning revolution, using the state of the art multimedia technology, closer scrutiny of what is being delivered reveals that much of the e-learning models that are around are little more than the old text based computer aided learning running on a global network (Dastbaz et al., 2006).

The community in this field advances in different topics, looking forward to making the promises and hopes come true, plus the evaluation of the diverse tendencies in virtual education systems position both Adaptive Systems and Intelligent Pedagogical Systems as front line topics in researches and proposals (ITS, 2006; ED-MEDIA, 2006).

A real and thorough customization requires stating an adaptation strategy, which implies defining the elements to adapt, the characteristics that determine when to adapt and a series of rules that manage the process. Particularly in the case of Educational Systems such strategy must also take into account the request of the International Community expressed in the 3rd workshop of Authoring of Adaptive and Adaptable Educational Hypermedia in Holland in the year 2005 (Cristea et al., 2005), in the sense of determining which the main characteristics to model in the student are, defining how to formulate the pedagogical knowledge in a reusable way while supporting pedagogical scenarios and regarding the cognitive styles.

This paper proposes a new class of customized virtual courses supported in a generic adaptation strategy and modeled through Multi-Agent Systems, while using Artificial Intelligence techniques. It also exhibits the analysis carried out and the obtained results that allow a clear definition of an adaptation strategy for the automatic generation of a customized course, based on the specification of features and components that will ease the process supported on metadata.

The rest of the document is organized as follows: section 2 outlines some concepts of adaptive systems, section 3 conceptually introduces the proposal to continue with the presentation of the development process for the multi-agent system, an overview of the experimental platform that supports the model is presented and described in the next section and the final section presents the conclusions and future work.

2. Personalized Education

As it can be seen on figure 1, the components susceptible of adaptability in an education system may be the interfaces with the student, the lesson plan, the educational strategies, the filtering of information, and the evaluative process, which involve the integration of individual with collaborative learning activities.

Adaptation must be achieved through a determined adaptation strategy, which implies defining which aspects to adapt, the conditions for such adaptation, the objectives pursued and the way in which it will all be done, in other words, What to Adapt, When to Adapt, the Adaptability Goals and the Adaptability Rules.
Karagiannidis et al. (1996); or outlining a reference context that determines the ambit of the adaptation behavior and the partial order of the adaptation cases and defines two main components: a set of adaptation triggers and a set of adaptation cases associated with the triggers (Paques et al., 2004).

The adaptation technologies in Web systems may be summarized in adaptive selection of contents, adaptive navigation support and adaptive presentation. Duque et al. (2006) refer that adaptation can also be seen at several moments of the educational process and that these techniques can be oriented to curriculum sequence, to adaptive support for collaborative tasks, to intelligent analysis of solutions, to intelligent information recovery and to knowledge level assessment.

3. Adaptive System for Virtual Course Generation

Proposing an adaptive model in educational systems requires the precise definition of a variety of components in such way that they may be handled in the adaptation process.

On one hand, the adaptation task must define the relevant elements of the student profile that determine the customization and, on the other hand, the domain of the course must be represented in such way that it can be adapted according to the needs of the learners, specifying the components able to be adapted, according to the focus of the system. The automation of this process requires and demands for a clear adaptation strategy that conjugates these elements through rules or algorithms, which balancing the expected needs and goals, will deliver a customized course to each student.
Facing this problem implies to join two different efforts, one being pedagogy and educational technologies, and the other, Information Technologies which design and build the systems that support the adaptation expectations. At this point, Artificial Intelligence Techniques have shown their advantages, including applying Case-Based Reasoning (CBR), Neuronal Networks (NN), AI Planning, Bayesian Networks (BN), Fuzzy Systems and Genetic Algorithms (GA). In some of the background documents there is an approach based on Multi-Agent Systems (MAS) which seems to be a promising alternative (Jaques & Vicari, 2005; Jimenez, 2006; Vicari, 2005; Merida & Fabregat, 2003; Martins & Diniz, 2004; Nakagawa & Kuroda, 2004, Silveira, 2001).

The proposed model is presented in figure 2. It shows the existence of a separation between the structure of the course (represented in educational objectives or competencies to be achieved) and the teaching materials that support the educational activities according to various pedagogical strategies, applied to the differences among learners. The most relevant characteristics inside the educational process are defined for the student in the psychological, psychological-learning styles), not permanent and technological contextual levels. His or her academic profile is saved in terms of the educational objectives achieved. In addition, specific tests are performed for obtaining initial values.

The adaptive strategy relates some elements to others in order to generate an initial lesson plan and, by means of monitoring the student’s behavior in the process, decides if it is necessary to re-plan. The planning and re-planning strategy becomes complex because of the way to express the course, the fine granularity of the educational materials (educational units) and the heterogenic characteristics of the students, though applying a variety of intelligent techniques helps overcome a large part of the difficulties without giving up on the objective.

Fig 2. Generation of adaptive virtual course (Duque et al., 2006).

Focused on taking into account the challenges set by the community, this proposal is oriented towards the definition of a generic strategy of adaptation that
allows the inclusion of diverse pedagogical and technological approaches. All of this is done referring the student profile, the specification and the organization of the pedagogical resources (any material or virtual object that can be used to create or develop competencies) and the components to adapt in the adaptation of the course. This situation certainly creates new challenges and makes the work more complex.

The path to follow may be oriented by the disintegration into functional blocks, without losing the systemic point of view, which leads to distributing the solution in diverse entities that require specific knowledge, processing and communication between each other. Having these characteristics, modeling the problem using a Multi-Agent System (MAS) seems to be a promising option. The main motivation for selecting MAS is the possibility to distribute the components of intelligence outlined by the solution on the proposed problem.

This situation has direct repercussions on the modular development of the system, which also makes it easier to refine or exchange each one of the aspects without substantially affecting the others, according to the approach chosen by the developer. Supporting such expectations, the theoretical reference proves that very good results have been achieved in solving similar problems to the one in discussion, based on pedagogical knowledge distribution and processing, which opens expectations in taking advantage of these possibilities.

4. Design and Construction of the MAS

Starting from the decision above, the design process for the system is initiated using the MASCommonKADS methodology as foundation, which defines the necessary models for the analysis and design phases and provides complete documentation; besides, other applications in similar cases report to have very positive results (Iglesias, 1998). Nevertheless, the experienced acquired suggests including some models from other methodologies such as MaSE (Multi-agent system Software Engineering) (DeLoach, 2005) (Hierarchical Objective Diagrams as support in dividing some complex tasks) and GAIA (Wooldridge et al., 2000) (Roles Model, important in clearly determining what can be expected from the agents).

Figure 3 shows some examples of the conceived models. For the description of the tasks that require knowledge is specified the control that determines how the elemental inferences are combined in order to achieve an objective. The description of the conversations among the agents is made both in graphical and textual representations. The textual depiction is schematized in templates, where both student agent and adaptation agent participate.

A complete diagram depicting the proposed system is presented in figure 4. The student agent allows handling diverse elements in the profile of the learner according to particular interests. Forms and tests supplied by the supporters of the included characteristics are used for input information, such as psychological tests, learning styles tests, socio-grams, and some figures directly obtained from the
system during the interaction process. For the update two pathways are established: a) new tests or forms, b) monitoring the actions of the student and in some cases through machine learning by using data mining techniques on logs and collected data.

The domain agent manages the structure of the course associated to an acyclic graph whose nodes are the Educational Objectives (EO) to be achieved, while keeping information of the Educational Units (EU) or Pedagogical Resources (PR).

The retrieval of the stored learning objects or elements is performed by the Local Retrieval Agent, which has only information about the way in which the resources will be received, permitting to use diverse visions for the resource composition, naming and allocation, though supporting standard technologies particularly related with learning objects, such as LOM (IEEE, 2002) and DCMI.

There is an agent in charge of the assessment processes, performing tests, input tests, and so on; who contains the required knowledge to classify and locate the student.

As it can be noticed, the adaptation strategy is embedded in the Planning Agent which is internally an Artificial Planning System of a Hierarchical Task Network (HTN) that allows the customized course to be created (Nau, 2003). Taking the process of generating a customized course to a planning problem implies defining the triplet \((S, T, D)\); where \(S\) represents the initial state of the student (academically, pedagogically, etc.) described in the language of the planner; \(T\) symbolizes the list of tasks to achieve in order to obtain the expected results; and \(D\) represents the domain of the planner conformed by operators (O) that define the direct actions that can be executed. They are of the form \((h(v)\ Pre\ Del Add)\) and the methods (M) that represent the macro operators that permit to “package” a list of actions and are of the form \((h(v)\ Pre\ T)\), or more general form as \((h(v)\ PreI\ T1\ Pre2\ T2\ldots\ Pren\ Tn)\).

For this translation process the required algorithms were previously defined and presented in (Duque et al., 2005). The following is obtained based on them:

\[
O = (EU.id \ (EU.prereq) \ (q) \ (h(EU.id)) \ (EU.size))
\]

where:
**EU.id**: EU identifier,  
**EU.prereq**: Prerequisite,  
**EU.size**: Size or cost of the Educational Unit (this variable could be replaced by instruction typical time or similar), and,  
**h(EU.id)**: Procedure that returns the **EO** that the given **EU** supports.

![Diagram of the Pedagogical Multi-Agent System proposed](image)

\[ M = (EO.id \cdot f(EO.id)) \cdot g(EO.id) \]

Where:  
**EO.id**: EO identifier,  
\( f(EO.id) \): Procedure that returns \( EO_{PRE}.prereq \),  
\( g(EO.id) \): Procedure that returns \( Sub\_OE_{n} \cdot OE.id \), and,  
\( (Sub\_OE_{1}, Sub\_OE_{2}, ..., Sub\_OE_{n}) \): Educational Objectives children or sub-objectives.

And  
\[ M = (EO.id \cdot (EU_{1}.LS \cdot EU_{1}.id) \cdot (EU_{2}.LS \cdot EU_{2}.id) \cdots (EU_{n}.LS \cdot EU_{n}.id)) \]

Where:  
**EO.id**: EO identifier, and,  
**LS**: Learning Style associated to \( EU_{n} \).  

From the course generation problem to a SHOP2 planning problem:  
Inputs: Initial conditions of the student (achieved goals and Learning Style), Educational Objectives proposed for the course.  
Output: Planning problem SHOP2 in the form \( (S,T,D) \)

Procedure:  
1. \( S = ((EOL_{1}, EOL_{2}, ..., EOL_{n}) \cdot LS) \)  
   where \( EOL_{n} \subseteq EO \), the \( EOL_{n} \)’s achieved by the student and \( LS \) is his/her Learning Style.  
2. \( T \): Set of tasks to achieve, expressed in terms of Educational Objectives: \( (EO_{1}, EO_{2}, ..., EO_{n}) \).
3. **D**: Domain conformed by methods and operators, obtained in the previous steps.

The SHOP2 planner, taking \((S, T, D)\) as inputs, returns a plan \(P = (p_1, p_2, \ldots, p_n)\), as a sequence of Educational Units that allow the student to achieve \(T\) from \(S\). The planning algorithm allows to advance from the initial state and start covering the required tasks according to \(T\), by the application of the methods and operators in \(D\) that support the declared “strategy”. At the end, the customized plan is deployed as a sequence of activities supported by the Educational Units (operators) that must be developed by the student in order to achieve the proposed objectives for the course.

In case that the execution of the plan does not produce the expected results or that the learner finds difficulties in achieving the educational objectives, it is required to re-plan the course locally or globally. As a good and simple alternative, the technique known as Case-Based Reasoning (CBR) is selected. The basic principal in CBR is that it offers similar solutions in similar problems, which allows reusing successful solutions for similar problems. Particularly for this case, it implies retrieving the information obtained by the system from successful experiences related with assisting the proposed objectives on students with similar profiles.

5. **SICAD platform, Intelligent System of Adaptive Courses**

Based on the previously established topics experimental platform Intelligent System of Adaptive Courses SICAD, was constructed. It is completely functional and can be used for the assembly of diverse courses and applying different pedagogical trends. It was developed based on free and multiplatform tools; therefore it can be installed both on Windows and Linux environments and it allows access from any platform that has a Web browser. The Web Server is Apache Software Foundation Tomcat, with support for the Database engine MySQL. The programs were developed in Java. The SmartUpload (which permits to upload files to Servlets and JSP) and MySQL _Driver_3.0.15. libraries were particularly used as well.

The system permits to administrate elements of the virtual course: Users, Educational Objectives and Educational Units, to construct courses by means of the Educational Objectives that compose it and to automatically generate the domain of the planner and to execute it for the personalized generation of each course, as it is presented in figure 5.

6. **Conclusions and Future Work**

Facing the limitations found in taking advantage of the latest technologies for Virtual Education Systems, particularly the lack of customization in the courses,
the proposal is based on defining the elements that must be taken into account in each student in order to adapt the course and, at the same time, associating these deficiencies with materials and activities. These materials and activities must differentiate, in practice, every student, looking for his or her academic and spiritual satisfaction, while generating motivation and projecting meta-cognitive mechanisms which, at the end, transform the process into more efficient.

It is very important to define the structure of the course and compose it with highly granular elements, which will help achieve a very detailed adaptation. These advantages generate problems in the phase of construction and in the manual management; plus, the techniques to be used in the solution play their specific role, particularly MAS, AI Planning, and Case-Based Reasoning.

This platform is in continuous improvement and new projects are being developed into it, which will allow the application to progress, particularly in tuning the execution process, the implementation of the assessment modules, and the development of adaptive interfaces.

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References


