An Open Adaptive and Multi-Subject Educational System for the Web

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Abstract: Nowadays the use of Internet for educational purposes is increasing, and it has therefore become an important basis for educational training. The access characteristics of this global environment originate new educational study areas whilst forcing the old ones to evolve. There exist many educational tools for the web but they are, in general, static, non-adaptive to students. This lack of adaptability can be due to the increment of the teachers workload produced by its inclusion in an educational system.

In this paper, we propose a web-based educational system whose adaptability lies on its self-tailoring in execution time to any subject or student. In addition, it reduces the teacher's workload by restricting the aspects that must be authored to those of the subject domain description. On this system, teachers, students and experts can interact each by a different workspace; however, the paper is devoted to the student view.

Introduction

Many systems providing web-based course management exist, but they are only useful for a specific type of population as they lack adaptability. Transferring courses to the web implies that the quantity and type of users to interact with these courses increases, so adaptability has become a main focus of the current research agenda.

To approach the mentioned issue in this paper we present an open, adaptive and multi-subject web-based educational system. First, we mention some related works, then we describe the objectives, architecture and functioning way of our proposal and we finish with some conclusions.

1. Background

Various Course Management Systems (CMS) are used for educational purposes on the Web. These systems (Blackboard [2], WebCT [10] and others) both provide the student with many communication resources and aid the teacher to generate deliverable material. Usually, courses created with these systems are not more than a static group of learning materials with a teacher defined learning order. As the sequence of learning is predefined and it does not vary according to the student characteristics, the courses are not adaptive.

This lack is very similar to that motivating the emergence of the intelligent tutoring systems (ITS) area; therefore, the technical results of the ITS field provides a sound basis to approach the new educational use of the Web, as it has already been shown in other research works. Web-based courses are used by a growing number of students of different types, with varied objectives and background[4], therefore, the necessity of adaptability on web environments has increased originating the area of adaptive web-based educational systems. On this context, several approaches are giving significant results.

On the one hand, the adaptive hypermedia field [4] tries to create learning systems on the basis of dynamic modifying pages and links according to some user's characteristics. Therefore, these adaptations concern both the presentation and the navigation support. The first one is related to adapting the content of the page to the student characteristics whereas the second one refers to the adaptation of the links in order to help students finding the best path on the hyperspace.

On the other hand, the Advanced Distributed Initiative (ADL) [8] pursues the access to high-quality education by means of materials tailored to individual needs. They work on the specification of a Sharable Content Object Reference Model (SCORM) in order to define a bank of learning objects that can be delivered by different learning management systems (LMS). A LMS is a server-based environment that controls the delivery of learning contents and tracks student progress. According to this, our objective is to propose a LMS capable of using a general purpose and multi-subject set of learning objects. The development of complex LMS that can *"assemble, reorder and redefine learning content to fit the real-time needs of the learner"*[8] is an important issue that is among our goals.

Some of the previous results obtained by our research group set the basis of this proposal. In [5], the core aspects of the pedagogical component of an intelligent tutor are described. A modular architecture based on the different tasks the pedagogical element must carry out – e.g., selection of contents and skills, pedagogic planning, delivery of instruction, supervision and diagnosis– together with a dynamic and domain independent planning approach are described. A generic tutor architecture respecting the classical separation of domain, student and pedagogical knowledge was its main result. As a next step, [1] describes the IRIS shell; its objective is to help human instructors to develop ITSs. It is able to generate a new tutor customizing the generic predefined architecture according to some teacher's criteria describing the domain structure, the student adapting characteristics and the general tutor delivery actions.

Our current proposal extends the previously mentioned work and defines a multi-agent architecture, that is capable of providing learning support in several domains by automatically adapting itself to multi-domain student features. This adaptation is done in such a way that the teachers' workload decreases. The system can be used on the Web and is completed with synchronous and asynchronous communication resources among users.

2. Objectives

Our objective is to build an adaptive and open multi-subject web-deliverable educational system that allows the interaction of students, teachers and domain-experts, each of them with different workspaces and viewpoints of the system.

For the teachers, our strategic goal is to reduce their workload, as we think this is one of the key issues for this kind of system to really be used. Consequently, teachers' workspace, must provide suitable tools to help them to develop their habitual tasks i.e.: planning of lectures, preparation and evaluation of assignments and exams, development of educational material, as well as to open the communication ways to let them dialogue with other teachers and students. Last versions of REDEEM[11] include some developments in this line comprising tools for the teacher with alike functionalities.

The domain workspace lets the domain experts or the teachers instead, develop the learning material. An authoring environment based on IRIS[1] is provided for that task.

The third workspace is the students' one, in which this paper is centred. A good students´ education is the result of the growing knowledge and skills obtained from the study of several interrelated subjects. Knowledge and learning strategies acquired in one of them can be, and should be, used whilst studying or learning the others. For instance, we all are aware of the use of good mathematical skills while solving physic problems. Therefore, a system covering the general aspects of learning has to comprise several subjects as well as relationships among them. In this proposal this idea is included, as the system is capable of adapting itself in an opportunistic way to the teaching of any available domain. However, determining the relationships among them is very challenging for the student. This is why the proposed system can help the student to select the best domain or section to work on. In other words, the system does not only support the learning of a concrete subject but it is able to guide the student on her global learning process.

Once the domain to work on has been decided, the system allows the student to do guided learning, general free-exploring and free-exploring through already studied material. For the system to tailor the teaching to her level and interests, the student, domain and pedagogical knowledge are of great importance. Following the main structure of ITSs, these three elements have been differentiated.

3. Architecture

Taking as a basis the previous work of our group, we have defined an adaptive, open and multi-subject web-based learning environment supported by a multi-agent architecture [6], as we want a distributed system easily scalable and modifiable. A multi-agent system is a set of autonomous agents that interact on an environment to collectively solve a task.

Like in the Retsina framework [9], each user is supported by a set of goal-directed agents that collaborate to solve user goals. These agents can be classed in three categories: information, task and interface; the system is completed with a set of knowledge sources.

Apart from the agents for coordinating the system and in charge of other system views (teacher, domain, expert), each registered student is supported by a dynamically generated agent network with the structure of figure1. Next, each component is described.

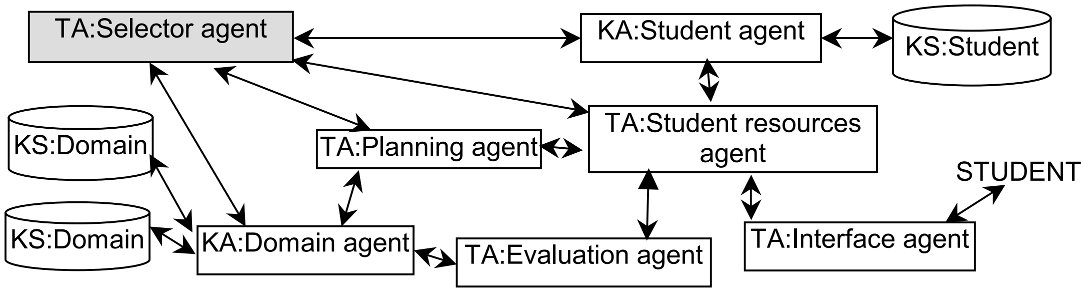

Figure 1: Architecture of the system

3.1 *Knowledge Sources (KS):*

Their goal is to provide the system with the needed knowledge about students and domains.

-*Domain KSs* contain all the information about the subject matters. A set of knowledge elements of different complexity and a meta-knowledge level-for structuring it- inspired in that of IRIS describe each subject. The knowledge elements are defined on a conceptual plane whereas a pedagogical plane specifies the relationships among components (requisites, pre-requisites and difficulty level) as well as some inter-domain information. The pedagogical plane permits the Planning Agent (see below) to select new elements to work on.

-*Student KS* contains the information about the student. For each student we have both general information, and information related to each of the studied domains. On the general level the name, age, description and other data valid for every domain are introduced. On the part related to each subject, the student model stores the estimation about the acquired knowledge (extended overlay model) as well as information about the motivation, type of student and other domain dependent information.

3.2 *Knowledge Agents (KA):*

Knowledge agents provide access to the mentioned KSs. There is a KA for each KS type and therefore, two knowledge agents are needed: Domain and Student. They are able to intelligently solve requests about their related KSs; concretely, they identify and extract the required information from the sources and then analyse and reason about it to produce an answer. Some possible requests are: to select an exercise or to obtain a concept, its requisites or the student knowledge level for it.

The Domain Agent can also solve requests about related information belonging to other domains. This important function allows the system to increase the quality of the learning process, taking advantage of the concepts and skills shared among different subjects.

3.3 *Interface Agents (IA):*

The agents on this class allow the communication among the users and the system.

As this paper is centred on the student workspace, there is a unique type of IA: the student one. The function of this agent is double; it can show to the student the learning material and can also interpret the student's goals from her interventions so that the Student Resources Agent can decide what to do next (see next section).

We have extended the set of possible goals of the student identified in [1] and classified them into three performance planes. The first one is related to the individual study with an intelligent tutor, the second one concerns the individual study with the help of a teacher or another student and the third one affects the collaborative work. The selection of tasks of a level, or the change of performance plane can be done both by the Planning Agent (see next section) and by the student.

3.4 *Task Agents (TA):*

These agents receive the student's goals, and make plans in order to solve them adequately. Some possible student's goals are: communication with other students or with the subject teacher, revision or introduction to a new topic and solving exercises. We identify two levels among task agents: abstract (grey on figure 1) and concrete or execution (white).

The agents on the concrete level carry out different kind of action to develop a learning session –control, instruct or communicate-. Among the possible actions there are: to select a new topic or to review a studied one, to open a communication channel, to request new exercises and their evaluation, to demand an explanation or to repeat one with different complexity level, and to ask for the background of an element.

In the guided learning style, the development of the session follows a pedagogical plan that is dynamically generated by means of a set of generic plans and rules to select them. Diverse plans and rules exist and the agents in the abstract level select the correct set to be used on each guided session according to some instructional criteria based on the student and domain features. That is, the abstract level does not carry out actions during a session but selects the needed pedagogical knowledge at the beginning of a guided session.

The agents in the execution level are: Student Resources Agent, Planning agent, and evaluation agent.

-*Student Resources Agent (SRA)*: It is in charge of fulfilling the student's learning goals by coordinating the rest of the agents. Modifications on this agent will allow to easily include more capabilities into the system without modifying the other agents. Therefore, as the changes are centralised the improvement of the system is facilitated to a great extent.

-*Planning Agent (PA)*: It is the didactic instructor [1] and generates an instructional plan by means of a set of skeletal plans and rules derived from a cognitive theory of instruction. The Selector Agent (see below) provides the PA with the needed pedagogical knowledge.

-*Evaluation Agent*: It is capable of diagnosing and evaluating the exercises proposed to the student. Its results are used for informing the student, updating the student model and modifying the current instructional plan.

The abstract level is formed by the Selector Agent.

-*Selector Agent*: This agent is in charge of selecting the pedagogical knowledge to be used on each guided session. The PA needs a set of skeletal plans and rules in order to generate an instructional plan. The plans and rules selected for a particular session depend on the current domain of learning, on the student adapting characteristics and on the possible tutor delivery actions. On IRIS, the selection of pedagogical knowledge is done according to the tutor behaviour features selected by the teacher-author. In our proposal the selection is automatically accomplished by the Selector Agent; thus, as there is no external interaction, the teacher's workload is reduced. The pedagogical knowledge to be used on each session is not determined at generation time but dynamically on execution time, at the beginning of each guided session according to the characteristics of the current domain and student. This makes possible to teach different changing subjects with several complexity levels.

Including a learning mechanism in this agent will allow the improvement of rules and plans selection along time.

4. How the System Works

The initial set of agents for the student -interface, resources, domain and student- are generated just after identifying her as a registered user.

Once the agents are initialised, the student can interact with the system using the provided interface. It shows the available domains so that the student can select the subject to work on. Next, some of the tasks that can be performed over each domain are mentioned:

-On the plane of individual learning with a tutor, the student can have two kinds of learning experiences. She can either do a guided session where the tutor decides the main instructional events of the session -taking into account the student's goals-, or she can do a mixture of free-exploring over the studied material and guided learning.

-On the plane of individual study with external help, system capabilities are increased to add interventions from a human teacher or a student. Thus, the student can ask help from a teacher or another student that can be selected either by herself or by the system.

-On the plane of collaborative work, the behaviour of the system is extended with some collective development tasks, such as solving exercises or carrying out group assignments. Groups can be formed [3] either by the system or by the teacher.

Sessions developed on the first plane need the intervention of the Planning Agent (PA) in addition to the initial set of agents, whilst the second and third plane can be executed without such component. The PA is generated by the Selector Agent and once it is generated it controls the development of the session interacting with the SRA.

5. Conclusions and Future Developments

We have proposed a multi-agent architecture to implement a web-based open, adaptive and multi-subject educational system. This system allows the student to do free-exploring, guided learning or a mixture of both as well as developing collaborative tasks and opening communication channels with other students or teachers.

The system provides a flexible learning environment for different changing domains by automatically deciding the pedagogical knowledge needed according to each particular student. Teacher's workload is reduced taking into account that he only has to define the knowledge sources as the agent network structure is automatically generated

At the moment this proposal is at a design level, with different refinement states for each of the identified agents. The system will be implemented using JADE[7] as it provides the basic structure for a multi-agent architecture. The general pedagogical rules needed have been already defined in [1], now we are specially involved on the selector and planning agents, as they form the basis of the system. For the core of the system, it is very important to determine the selection characteristics, which will allow to automatically generate the planning agent, as well as to establish the student objectives on each performance plane and the characteristics that will permit to change the domain on execution time.

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