A Multi-Agent Architecture to Provide Adaptive Learning Content in Moodle

Priscila Valdiviezo D.*, Inés Jara R.*, Martha Agila P.*, Paola Sarango L.*, Rodrigo Pesántez M.*, Miguel Rodriguez-Artacho**

*Virtualization Unit, School of Computer Sciences, Universidad Técnica Particular de Loja.
**LSI Department. ETSI IT, Universidad Nacional de Educación a Distancia (UNED).
{pmvaldiviezo,dijara,mvagila,cpsarangorvpesantez}@utpl.edu.ec
M.miguel@lsi.uned.es

Abstract. This paper proposes an agent-based adaptive architecture to extend *Moodle* in order to support instructional decisions and adaptive behaviour. The paper describes the characteristics, functions, and interactions of the agents which take part in each module of the adaptive architecture. In addition, we describe the origin and function of ToDei, the proposed intelligent agent for Instructional Decision Making. This agent is in charge of collecting information generated by the rest of agents and deciding what is best for the final users, tutors and students, taking into account their attitudes towards the learning environment.

Keywords: Intelligent agents, adaptive educational systems, intelligent systems, user modelling, tutor modelling.

1 Introduction

One of the trends of Interactive Teaching-Learning Systems is the incorporation of components that permit the generation of a teaching-learning process based on students` preferences and needs. This is characteristic of Adaptive Educational Systems (AES), which needs intelligent agents for independent-learning of the system and communication among the components.

Adaptation to the learner needs is a key challenged in e-learning systems. Despite the first approaches of CAI systems [cita CAI], based in the Skinner behaviourist models, current trends offer much more variety and richer interactions. According to Merril [1] the principles for an effective learning process in learning environments are effective when (a) they are problem-based and (b) learning environments are based on the principles of instruction. These principles consider that learning is facilitated when (i) learners are engaged in solving real world problems (ii) existing knowledge is activated as a foundation for new knowledge (iii) learners are requested to use their new acquainted knowledge to solve new problems and to integrate it in their everyday work. In this context, the use of traditional virtual learning environments (VLE) like *Moodle* offers little innovation or possibilities to implement the principles mentioned

above. As knowledge acquisition and the process of learning is not only a one-to-one basis between the learner and the matter, the capabilities of the VLE need to be enhanced in order to incorporate flexibility and understanding of the learner's needs.
The proposed architecture is based on the main areas of adaptation defined by Brusilowsky [2] providing presentation and navigation adaptation using intelligent agents associated to different modules in Moodle. This multi-agent methodology recently appeared as a good companion of adaptive distributed educational systems. The use of intelligent agents has evolved from the beginning of the ITS discipline as an adaptation to the VLE and as part of the use of web-based environments dealing with a distributed architecture. User adaptation using intelligent agents has been developed using several approaches. For instance as users' self test, like in [3] that provides an adaptive testing tool to fit the student's level of knowledge, where questions are generated automatically; or integrating agents in VLE as in [4] where educational content is made available by means of a process of re-categorization carried out using intelligent agents within the VLE.

2 VLE-MOODLE

From all the VLE open sources available in the web, Moodle is the most widespread and used around the world. Currently, there are 56357 sites from 210 countries registered as Moddle[1] sites. They are supported by a development community that provides current updates and support. Due to the previously mentioned services and to the portability and modularity that characterizes this community, it has been easy to present a proposal with an adaptive focus that contributes to the growth and exponential development of the VLE open source with tendency to an AES.
The Moodle structure is made of three main components: the professor, the classroom in which the educational process is given, and the students. Furthermore it gives each one of the student's different resources and activities, to give advice to students, and to facilitate the interaction between student to student, students to professors and vice versa. If there is not information related to the user preferences, the sequence navigation, the document evaluation, and the knowledge level, the teaching-learning process will be developed in a general way for all the members of a course. And a personalized service will not be offered to each student. One alternative to such problems is to focus Moodle on students' needs, trying to adapt this system to each one of the students and training them according to their learning styles as well as adjusting the system to the students' needs. For this reason, a structure that allows Moodle to be adaptive is necessary. This proposal is done considering the studies developed in [5] [6]. Furthermore, it is considered a multiagent structure that needs to be easily applied to the modular architecture of Moodle and offers a dynamic adaptation through learning.

[1] Moodle.org. http://moodle.org/sites

3 Adaptation Task

The main function of the adaptations tasks is to reach the development of the fundamental faces of the AES. They have a lot of influence in the user modelling since the characteristics that are necessary for execution by the user are identified here. According to [7], in order to identify an adaptation task it is necessary to consider the following aspects: the element to be adapted, the objective to be achieved and the technique to be applied. Also, in [7] the author states that the adaptation tasks which can be considered in an educational virtual platform are:

Adaptive support for collaboration: gathers the user models which are better adapted regarding characteristics and level of knowledge. Depending on the context, different objectives can be defined in this task and, for each objective a set of techniques can be determined. For instance; in order to accomplish the objective of Forming Work Groups, the following techniques may be applied:

1. *To define related profiles.*
2. *To suggest contacts of other students.*

Adaptive support for navigation: the main function is to guide students during their period of interaction with the system by showing various alternatives according to their needs, once they have a defined a profile. Another function is to give a tutorial to students if it is their first time using the system. One of the objectives to be achieved in this task is: To show or hide links which are relevant to students through the link hiding technique. This technique disables links which are not important to students. Another technique is recommending the “next best” link to each user.

Adaptive support for presentation: consists of presenting the content and the pages to users based on their preferences or previous knowledge. One of the objectives that can be achieved through this task is *sort* by using the technique of presenting elements that can be shown to students according to their needs.
Once adaptation tasks with their own objectives and techniques have been defined, it is important to conduct an analysis of the existing information that would be necessary for each component or module, with the purpose of completing the adaptation process. The adaptive architecture for Moodle is described below.

4 Adaptative Logical Architecture Proposed for Moodle

The proposed architecture of AES for *Moodle*, has four principal modules: tutor module, student module, user interface module, and knowledge base. Each of the first three has an intelligent agent that performs tasks for each module. For communication and interaction among agents of each component, the agent called ToDei has been defined. Its goal is to take the information of each module and decide the best method of instruction for the final user. In the knowledge base module, the development of

one or more agents can be considered, depending on the way the information is structured (taxonomy or ontology, for example). For the present case, no agent has been defined in this module since its basic functions will be performed by the ToDei agent. For each agent, the principal functions are defined. Therefore, the one who works on the tutor module has didactic-pedagogical functions and tutor modelling, and the student module carries out the creation of student models and information updating. The user interface module (student-tutor) determines the most appropriate interface for each user based on the hardware and software used for the connection. The ToDei agent communicates and determines the best instruction for the user.
The components of the different modules proposed for AES are based on research based on an analysis of available information on the Moodle virtual platform, which permits definition of the necessary task adaptation to acquire an adaptive approach. As stated clearly before, the components and intelligent agents that will intervene in an adaptive architecture, using the Moodle virtual platform as a base, are shown below.

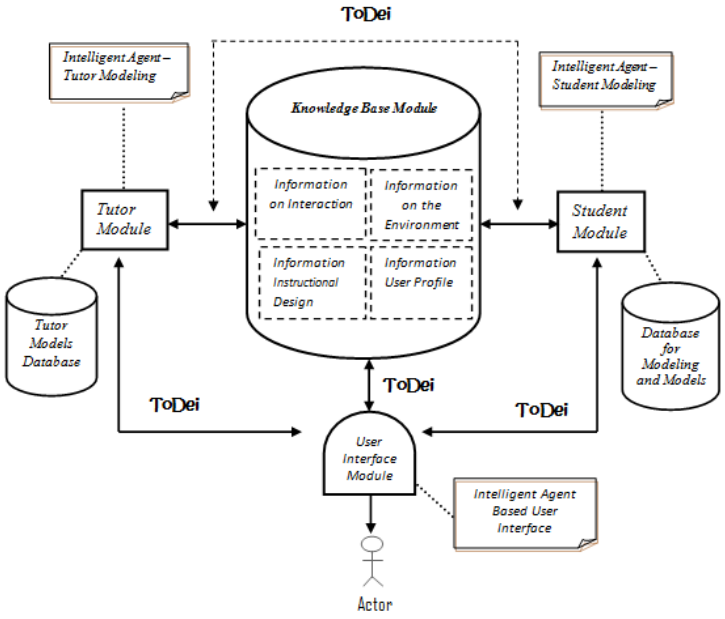

Fig. 1. Moodle's Adaptative Logical Architecture

4.1 Tutor Model

The instructor, who is an actor in (traditional) Moodle, becomes a component in this type of architecture, in which the best way to make information available to students is identified. This function is performed by an intelligent agent, which will make decisions according to various variables that could be considered to provide knowledge to students. This activity is supported by the instructional design and the

different versions of the material made by instructors. The different tutor models generated by the agent are stored in this module. At the same time, this agent is in contact with the knowledge base module in order to retrieve and store information. The intelligent agent, which is associated with this module, is the intelligent agent for tutor modeling that must perform the following functions: a) Pedagogical-didactical (teaching style), b) Tutor modeling (implementation of contents).

Intelligent Agent for Tutor Modeling

The tutor modeling agent has been designed to perform the following functions:

Didactical-Pedagogical. Each instructor has his/her own style to encourage learning among students, which is perceived differently by each student. This situation is what the intelligent agent attempts to simulate and learn in order to guide students in what and how to learn. According to students' acceptance and response to a particular style, the agent will be able to classify what teaching form is the most accepted by a particular student profile. Thus, once the agent has learned, it can choose the most appropriate style for each user based on his or her profile.

- *Tutor Modeling.* The main feature of this function is the analysis of the organization and implementation of contents according to the experience that the agent has acquired. This process will begin with a modeling that gathers information on activities and resources proposed to students and on their success rate. Based on this experience, the agent will learn the best way to implement contents.

After analyzing this information, some tutor models, which can be applied to determined student models, can be defined. Tutor models may vary depending on the level of learning and experience acquired by the agent. This will permit the definition of more concrete models that can be best adjusted to a particular type of student.

4.2 Knowledge Base Module

This module has various information sources such as a) student's personal data, b) interaction data, c) environment data, and d) information on instructional design. This information can be organized into different structures such as taxonomies, conceptual maps, thesaurus, and even ontologies.

4.3 Student Module

Regarding AESs, students generate the underlying information for adaptation. For this reason, in an adaptive architecture, this actor turns into an independent module in which, based on the students' characteristics, needs and preferences, different models are generated.

Intelligent Agent for Student Modeling

The agent for student modeling performs some functions in this module. These functions include: a) Creation of Student Models, based on a previous model, in which explicit and implicit variables are defined and include navigation environments, learning styles, learning levels, cooperation levels and interaction levels. Once models have been created, the agent will be able to categorize the different student profiles according to the model with which they share similarities. This will favor a more significant learning experience. b) Information Update, this function collects information about the student from the moment the student accesses the system. This information is updated by the agent, which is in charge of monitoring various activities, routes, and actions of the student in the system. After comparing some characteristics that students accumulate in their profiles, and if necessary, the agent will be able to change the model to which the user was assigned and determine the progress of the user in the system.

This agent interacts with the knowledge base through the instructional decision making agent (ToDei), from which data of each profile are retrieved and saved once the student has been identified in the system or when the student exits the system.

4.4 Interface Module for Users

This is the component that shows all the information to the students, trying to capture their attention and keeping them motivated. In this module, we identify characteristics such as the type of browser used, type of device used for access, and the available connections.

Intelligent agent for user interface

The objective of this agent is to determine the best interface to be offered to each user based on the hardware and software used for the connection. The means of connection, the software, and the equipment used are different for each user and for this reason each has different presentation needs. For example, if a student accesses the system from a cell phone, he would only need the most necessary files, but if a student accesses from a carry-on computer with a good bandwidth, he would be able to watch videos and animated films and listen to audio files. The intelligent agent for user interface should learn these conditions and determine the most appropriate type of system interface for each one. This learning can be acquired when students can interact with the offered interface and when the identification is accepted or denied. This will help classify it as appropriate or inappropriate.

4.5 Intelligent Agent for making instructional decisions (ToDei)

The adaptive architecture that has been proposed is a dynamic structure and multi-agent that allows learning, communication, and independence of each component of the system. In all the components there are agents that facilitate the execution of the process and a particular defined process, but in order to fulfil the requirement of offering the use of the adaptive effect, the communication and interaction of all the components of the architecture are necessary. Consequently, the intelligent agent ToDei is used. The objective of this intelligent agent is to fulfil these functions as well as to transmit the content to the user. Furthermore, considering the characteristics and greatest needs, it decides the best way to offer information generated in this process. ToDei receives information through the module for user interface, specifically the one generated by the agent for interface. It is the first to have contact with the user because it communicates with the module for students where the information regarding the profile (stored in the knowledge basis) and the model student (stored in the module for students) are restored. They are then sent to the module for the tutor where, according to the tutor model assigned for the model student, the most appropriate instructional design is offered. Finally, ToDei displays the results of this process to the user. At this stage, the intelligent agent chooses how to show through the interface the content generated based on the style best suited to the learning process of the student. As observed, ToDei is the only agent present in this architecture which has the function of restoring, transmitting, and sending information through the different modules of the system.

Structurally, the intelligent agents are formed by sensors, effectors, states, and the environment. In this proposal, ToDei has different inputs which are derived from the modules: user interface, students, knowledge basis, and tutor. They generate communication and reception of information through the agents that interact inside each module. The changes generated by such agents are received through the sensors of the ToDei agent; they are processed in the different action-reaction rules (rules of inference) of the agent. Finally, the resulting actions are sent through the effectors to the components that have generated the environment inputs of ToDei and in the same way are stored in the agent memory (states) for its self-learning. The structure and the process carried out in ToDei are illustrated in the following chart:

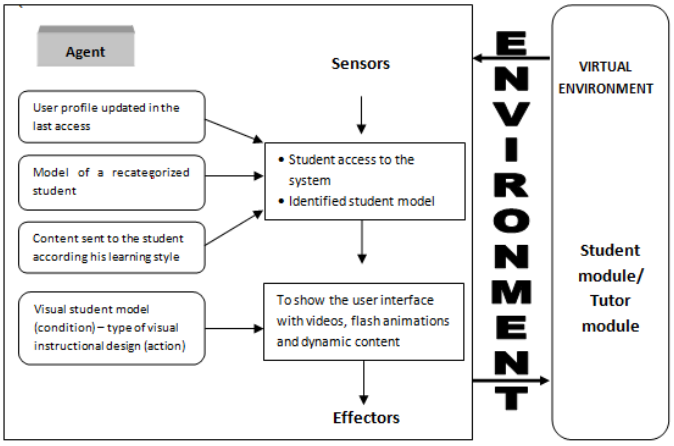

Fig. 2. Example of the structure of ToDei Intelligent Agent

Currently, the user model and part of the design of the instructional decision-making agent (*ToDei*) are being developed. The user model agent performs the following functions: a) Creates student models based on a previous model, b) Categorizes student profiles, c) Monitors users while they interact with the platform, d) Updates student information. The *Todei* agent will present the information according to the categorization of the student profile.

5 Conclusions

Moodle offers courses, content, as well as communication and interaction tools to all students as well as differences for their individual characteristics or preferences. This aspect can be improved by including intelligent components, thus providing a personalized teaching-learning process. The adaptive architecture proposed in this research can be applied to any educational platform. In this architecture, information about student and contents can be managed. The definition and implementation of intelligent agents in the components of a platform for a Moodle virtual platform do not imply the disappearance of the main actors: professor and student. On the contrary, this platform is a support that helps to reduce the teachers` workload and permits them to focus their efforts on creating good relationships with students to achieve success in learning. Although they have the same structures, each one of the proposed agents is functionally different but depends on the module on which it is operating. The ToDei agent constitutes the main component inside this architecture since it allows visualization of the adaptive effect generated by the interaction of the components.

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