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LEARNING OBJECTS & LEARNING STYLES AS A FOUNDATION FOR A MULTI-AGENT WEB-BASED EDUCATION SYSTEM

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ABSTRACT
The ability of Web-based education systems to adapt to individual learners' requirements has been enhanced by the adoption of multi-agent technology. We have developed a novel multi-agent system, which incorporates learning objects, and is based upon a learning style theory as the pedagogic foundation for its adaptivity. In this paper, we describe the design and implementation of the system, and discuss some of the research issues.

KEY WORDS
Multi-Agent systems, Web-based Education, Learning Objects, Learning Style

1. Introduction

The emergence of the Internet has provided new opportunities for delivering educational material, including use of the Web as a platform-independent medium for learning and teaching. Learning materials can be based in a single place and remotely accessed by students [1]. Web-based education offers the potential to realise opportunities for lifelong learning through its student-centric focus [2].

Although there are many Web-based educational applications, methods to implement adaptivity form a subject of ongoing investigation [1]. It is important to be aware of the differences between learners, and this is especially relevant during the current expansion of tertiary education to a greater proportion of the population [3]. Therefore to enhance adaptivity in education applications, including Web-based education, it is essential to be aware of the differences between the learners. The differences have been described as "learning styles" by educationalists.

Multi-agent technology, influenced by advanced information and Internet technologies, appears to be a promising approach that addresses the challenges of modern day education [4]. Although there are some multi-agent technology applications in Web-based education, many lack a robust pedagogic foundation.

2. Introduction of Related Technologies

In order to investigate adaptivity in Web-based education, we have combined a technological approach informed by appropriate pedagogy.

2.1 Agent Technology

Agent technology is a relatively new paradigm for developing software systems [5]. A wide variety of definitions for agents have been proposed, but until now there is no universally accepted definition. However, we can consider an agent as being a software entity that is capable of carrying out flexible autonomous activities in an intelligent manner in order to accomplish tasks to meet its design objectives, without direct and constant intervention and guidance of humans. Depending on the roles of agents in the different environments in which they may be deployed, their abilities vary significantly, and this has motivated the adoption of different definitions of an agent. However, we still can identify essential and commonly agreed properties of agents, which include: a*utonomy*, *proactivity*, *responsivity*, and *adaptivity*. Agents should know users' preferences and tailor interactions to reflect these [5].

Multi-agent systems contain many agents that communicate with each other. Each agent has control over certain parts of the environment, so they are designed and implemented as a collection of individual interacting agents. Luck *et al.* remark "Multi-agent systems provide a natural basis for training decision makers in complex decision-making domains [in education and training]" [6]. Multi-agent systems can also substantially contain the "spread of uncertainty", since agents typically process information locally [7].

2. 2 Learning Objects

Many learning materials are distributed using Web technology. Most of them are currently developed for a specific purpose, for example, courseware is usually for a specific module, and the content probably will not be

reused or will only be reused for a few times. Both for educators and learners, the concept of *learning object* has been proposed to address these issues.

A learning object is a "self-standing, reusable, discrete piece of content that meets an instructional objective" [8]. Learning objects may be tagged with meta-data so that their identity and content are available to software systems, which use them. The decomposition of educational content into learning objects is analogous to the decomposition of an object-oriented program into objects and classes, and permits an individual learning object to be used in a variety of educational contexts.

When Web-based education requires customization of content to enhance the adaptivity, the learning object concept facilitates a just-in-time approach to customization. Modular learning objects maximize the potential of software that personalizes content to achieve adaptivity by permitting the delivery and recombination of material at the level of desired granularity [9].

2.3 Learning Style Theories

People never learn in a same way. The concept of *learning style* has been introduced by educationalists, and is the subject of increasing academic interest. The term is used as a "description of the attitudes and behaviours that determine our preferred way of learning" [10].

Learning styles depend on a variety of factors, and are individual to different people. Even for the same person, it can change over time. Learning styles may also differ between men and women, and between children and adults [11]. In this paper, we restrict our view of learning styles to those applicable for students in higher education.

Models used to classify students' learning styles include Kolb's Learning Style Inventory [12], Myers-Briggs Type Indicator [13] and the Felder-Silverman Learning Style Model [14].

3. Combining the Technologies

Agent technology is a promising new information technology that has already been applied in several areas, such as manufacturing, air traffic control, electronic commerce, and business process management [5].

In the context of adaptive education, agent technology can provide a dynamic adaptation not only of domain knowledge but also of the behaviour of individual learners, and has already been used in a number of educational tools. However, most systems incorporating agent technology, such as [15, 16, 17, 18, 19], have decoupled the agent technology from the pedagogic foundations of the system, and each tool emphasises a particular aspect, such as training, group work, or human resources requirement. Each has its individual ways of organizing the learning materials, and few have considered the effect of different learning styles. The use of learning objects in such systems is rare, although the technology has begun to be used in non-adaptive training software [20].

We have developed a novel approach to the problem of supporting adaptive learning in Web-based education. In our multi-agent system, we have incorporated learning objects as the way of organizing learning materials, and the students' learning styles are being concerned when the agents create individual learning path for the students. In contrast to other agent-based pedagogic architectures, learning style schemes form the pedagogic foundation for adaptivity and the use of learning objects.

The learning style theory we have adopted in the system is the Felder-Silverman Learning Style Model. Several learning style theories have been considered, such as the theories mentioned before, and Gardner's Multiple Intelligences [21], etc. The reasons we choose Felder-Silverman Learning Style Model [14] are:

- it has been validated by pedagogy research [22], and
- the number of dimensions of the model is constrained, improving the feasibility of its implementation.

4. System Architecture

The multi-agent system (figure 1) is composed of five agents: the *Student Agent*, the *Record Agent*, the *Modelling Agent*, the *Learning Object Agent*, and the *Evaluation Agent*. The Student Agent is in charge of communicating with students, and the Record Agent keeps all of the information about each student. These two agents are designed to satisfy the communication and the information storage requirements. The Modelling Agent creates models of students' skills and learning objectives, and the Learning Object Agent manages all of the learning objects. These agents are designed to model students' learning and to organise the learning materials. The Evaluation Agent ensures learning objects are given in individual and adaptive learning paths to each individual student, and is in charge of quality control of the learning objects output.

The Student Agent, the Record Agent, and the Modelling Agent do not have direct control of the learning objects, but they have very important roles in the system. The Learning Object Agent and the Evaluation Agent directly interact with the learning objects and learning styles. The

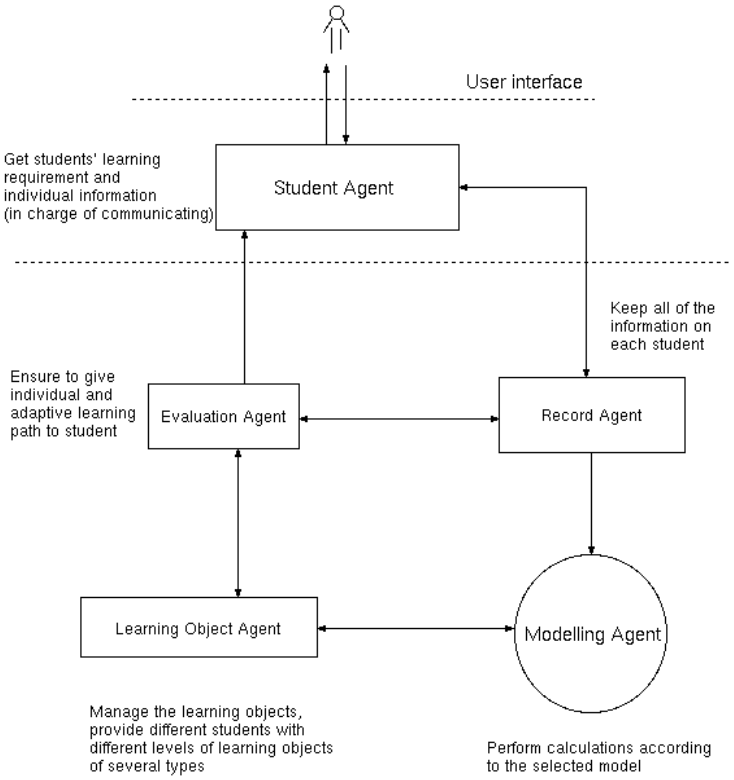

Figure 1: System Architecture

Student Agent, the Record Agent, and the Modelling Agent are in charge of communication, information collection and storage, and student modelling respectively. Without these functions been executed, the Learning Object Agent and the Evaluation Agent will not be able to organize and deliver learning objects in a proper way to students.

In the rest of this section, we will give a relatively brief introduction of the Student Agent, the Record Agent, and the Modelling Agent, then we will explain the Learning Object Agent and the Evaluation Agent in more detail.

4.1 Student Agent

The Student Agent (figure 2) takes charge of communicating with the student, and it is a BDI-based agent, which uses means-ends reasoning (or planning), the process using the available means to decide how to achieve an end [23]. When the student first logs into the system, it initially engages in a dialogue with the student in order to ascertain the knowledge level of the student, and to get information about the student's learning requirements, such as which module the student wishes to participate in, or what knowledge the student wants to gain. During the time the student is in the system, it records all of their actions, such as the time they spend engaging in each activity presented to them by the system, clicking times, active or not, etc.

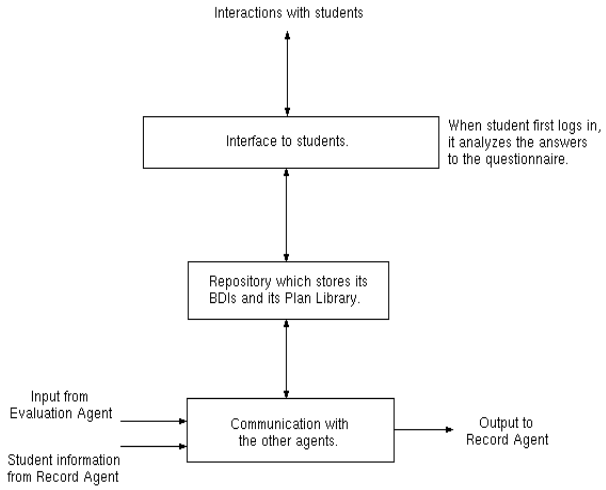

Figure 2: Student Agent

4.2 Record Agent

The Record Agent (figure 3) keeps all of the information about each student. Since the type of data received from or sent to the other agents may be unpredictable, the Record Agent is a BDI agent supporting beliefs about its ability to provide those data, and desires to support those agents appropriately.

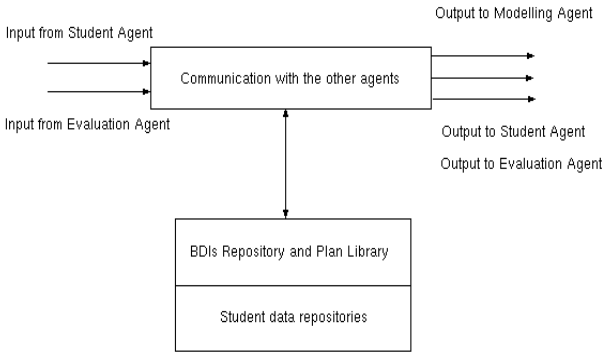

Figure 3: Record Agent

4.3 Modelling Agent

The Modelling Agent (figure 4) generates a representation of each student based on their academic progress and learning desires, returning its results to the Learning Object Agent. This agent requires a large volume of data, supported by its own regularly updated knowledge base.

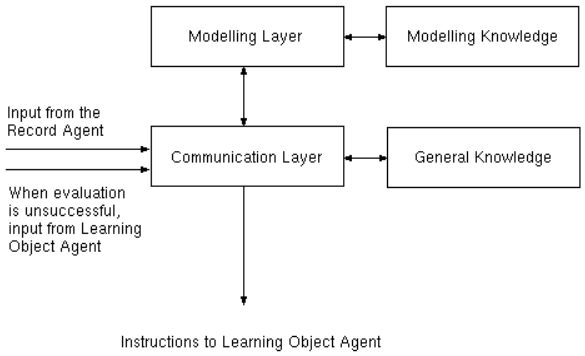

Figure 4: Modelling Agent

4.4 Learning Object Agent

The Learning Object Agent (figure 5) manages the learning objects, which are organized in different levels of difficulty. According to instructions from the Modelling Agent, it provides different students with appropriate learning objects. This agent is a hybrid agent in which its subsystems are arranged into a hierarchy of layers. Communication with the Modelling and Evaluation Agents is handled by a *communication layer*, which supports a *learning path layer* (which handles individual students' learning paths according to the learning style scheme). The learning objects management layer then handles a repository of learning objects.

The *learning path layer* adopts the Felder-Silverman Learning Style Model [14] to organize learning objects to fulfil different students' requirements. The learning objects in the *repository* are categorized by items of the learning style model. Organization of the learning materials as learning objects, based on a pedagogic learning style scheme in an agent environment, is a distinct characteristic of this architecture, which distinguishes it from existing pedagogic agent-based systems.

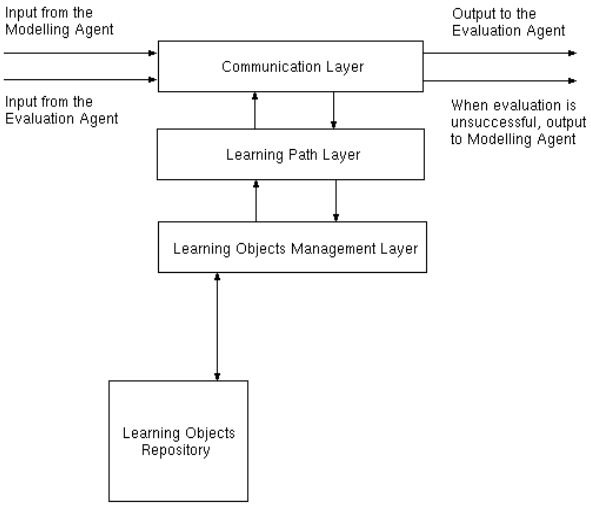

Figure 5: Learning Object Agent

4.5 Evaluation Agent

The Evaluation Agent (figure 6) ensures that learning objects are presented in an individual and adaptive learning path to each student, using *all* the student data from the system to evaluate which learning objects are sent to students. The Modelling Agent may not use all of the available information on a given student, and can only advise the Learning Object Agent.

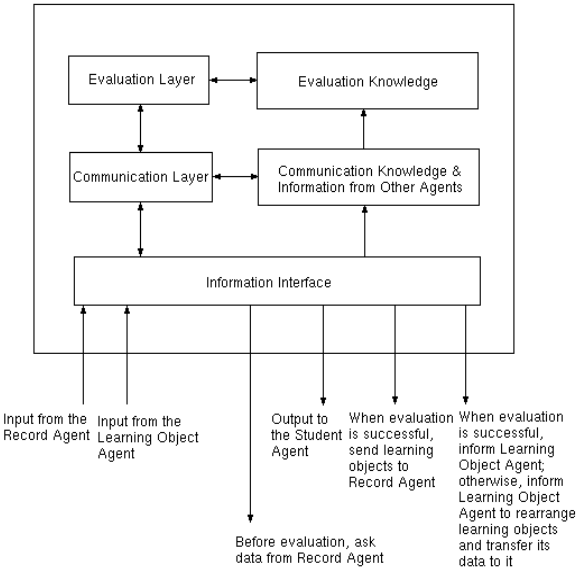

Figure 6: Evaluation Agent

If the selected learning objects are evaluated as appropriate for the student, the series of learning objects are sent to the Student Agent directly, otherwise the Evaluation Agent requests the Learning Object Agent to resend learning materials. Then the Learning Object Agent transfers these and asks the Modelling Agent to model again by using the data and suggestions from the Evaluation Agent.

The Evaluation Agent is a hybrid agent capable of reactive and proactive behaviours. It has a vertical layered architecture similar to InteRRaP [24], consisting of an *information interface* supporting two layers, each with its own knowledge base containing information repositories. The Agent has an open architecture and the Evaluation Layer has plug-in functionality, allowing different evaluation schemes to be incorporated in addition to the current fuzzy logic based scheme, thus offering the possibility of supporting other technologies in the future.

4.6 Using the system

When the student first logs into the system, the Student Agent enters into a dialogue with the student to ascertain the student's learning requirements. After initially analyzing the answers, the Record Agent is sent the student's learning requirements together with a suggested knowledge level for the student. These items of information are recorded and then passed to the Modelling Agent, which then sends results and instructions to the Learning Object Agent, which arranges the first batch of learning objects to be sent to the Student Agent according to the result of learning style analysis (which happens in the Leaning Path Layer) and difficulty level of the learning objects, which are also organized according to the learning style scheme. These learning objects are first sent to the Evaluation Agent, which checks the student's data from the Record Agent to evaluate whether the learning objects are suitable for this student. If the evaluation is successful, the series of learning objects is sent to the Student Agent (and then to the student) and recorded by the Record Agent. Otherwise, the Evaluation Agent asks the Learning Object Agent to provide alternative learning objects. After the student has used the learning objects, response data is returned to the Student Agent, which transmits them to the Record Agent.

5. Evaluation and Implementation

Several case studies have been used to verify the consistency of the proposed architecture, including first year undergraduate programming topics, covering introductory Java programming and UNIX shell programming. The Learning Object Agent is currently developed in JADE (Java Agent DEvelopment Framework), and we are working towards the implementation of the prototype system architecture.

As mentioned above, in the *learning path layer*, of the Learning Object Agent, the Felder-Silverman Learning Style Model is used to organize learning objects to fulfil different students' requirements. In the *learning object repository,* the learning objects are organized according to the dimensions in the adapted Felder-Silverman Learning Style Model. The learning objects deployed in the repository include learning objects for Introductory Programming [25], and some learning objects from CodeWitz [26].

6. Discussion

Learning style theory is a pedagogic foundation of the system, and learning objects provide a way of organizing learning materials for individuals. From a technical aspect of the system, the adaptivity requirement suggests that the set of interactions and communications within the system should be dynamic. The use of intelligent agents is appropriate since it allows us to abstract the data at a higher level than that which would be appropriate for conventional software technologies, and enables us to conceptualize the system in a natural fashion.

The Student Agent and the Record Agent is each supposed to make decisions according to its knowledge, so is naturally a BDI-based agent [7]. A deductive reasoning agent, was considered, however it is doubtful whether such a logic-based agent can react effectively in a time-constrained environment. The Learning Object Agent, the Modelling Agent and the Evaluation Agent need to perform relatively complex functions, so only a hybrid architecture, in which the subsystems are arranged into a hierarchy of layers, can satisfy these requirements.

For the requirement of adaptivity, the material in the system is not constructed for a specific course or module, but to meet individual needs; so learning objects are incorporated within the architecture to address this requirement.

The way we have incorporated agent technology and learning objects, supported by learning styles, is a new and contributing approach for achieving adaptivity in Web-based education.

7. Conclusions and Future Work

In this paper, we have presented a Web-based multi-agent system incorporated reusable learning objects and using a learning style scheme as the pedagogic foundation for adaptivity. A prototype of the system has been developed, and the Learning Object Agent has been implemented. In addition to the implementation of the complete system, future work also includes optimising the architecture, and evaluation of the system effectiveness and efficiency.

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