Collaboration and the Knowledge Economy: Issues, Applications, Case Studies
Paul Cunningham and Miriam Cunningham (Eds)
IOS Press, 2008 Amsterdam
ISBN 978–1–58603–924-0

MODA: A Micro Adaptive Intelligent Learning System for Distance Education

Fatma Cemile SERÇE[1], Ferda NUR ALPASLAN[2]
[1]*Department of Information Systems Engineering, Atılım University*
P.O. Box 06836 , İncek Gölbaşı, Ankara, Turkey, E-mail: cemileserce@gmail.com
[2]*Department of Computer Engineering, Middle East Technical University, 06531 Ankara, Turkey, E-mail:* alpaslan@ceng.metu.edu.tr

Abstract: The paper presents a multi-agent module, called MODA, to provide micro-level adaptiveness in learning management systems (LMS). The adaptiveness provides uniquely identifying and monitoring of the learner's learning process according to the learner's profile. The paper covers the pedagogical framework behind the adaptation mechanism, the architecture of MODA and its agents, the protocol providing communication between MODA and LMS, and a sample application of the module to an open source learning management system, OLAT. The study also discusses the possibilities of future interests.

Keywords: Adaptive Learning Systems, Intelligent Learning Management System, Multi-agent Systems, Distance Learning, Learner Profile

1. Introduction

Adaptiveness is a crucial issue in today's online learning environments (OLE). In [1], it is argued that virtual learning environments (VLE) are best at achieving learning effectiveness when they adapt to the needs of individual learners. Learning management systems provide educational services to a wide range of students and they can help students to achieve their learning goals by delivering knowledge in an adaptive or individualized way [1]. In [2], it was argued that as long as the competition on the market of Web-based educational system increases, "being adaptive" or "being intelligent" will become an important factor for winning customers. Web-based adaptive intelligent education systems inherit the advantages of both Intelligent Tutoring Systems (ITS) and adaptive hypermedia systems[2].

Brusilovsky provides some examples of adaptive systems such as InterBook [3], CALAT [4], ACE [5], ELM_ART II [6], ILESA [7], etc. Those systems support different intelligent and adaptive technologies. The author mentions some of technologies including curriculum sequencing, intelligent analysis of student's solutions, interactive problem solving support; adaptive hypermedia technologies such as, adaptive presentation and adaptive navigation support; web-inspired technologies like student model matching, and so on [2].

Pedagogical agents are autonomous agents that support human learning by interacting with students in an intelligent learning environment. They extend and improve upon previous work on intelligent tutoring systems in a number of ways. They adapt their behavior to dynamic state of the learning environment, taking advantage of learning opportunities as they arise. They can support collaborative learning as well as individualized learning, because multiple students and agents can interact in a shared environment. The use of agents in providing adaptiveness has been experienced in some studies such as ADELE [8], PPP Persona [9], etc.

Although these adaptive systems provide important adaptive features, it is not possible to integrate any of them with an existing LMS. Most of them are designed to be used as

standalone systems. However, there are lots of LMS used in practice and it might be very effective to plug adaptive features to these already existing and widely used learning management systems.

In this study, a multi-agent intelligent learning system module, named MODA, is proposed. The system is designed to be plugged into any LMS. The aim of MODA is to provide adaptive features to the learning management systems. It provides micro-level adaptation, because, it tracks the learner behavior during the interaction and adapts the content continuously. An LMS, when integrated with MODA, becomes an adaptive learning management system. MODA applies a conceptual framework to be adaptive [10]. This framework bases on the idea that the adaptiveness is the best matching between the learner profile and the course content profile. The framework takes its background from the learning styles and the content types (30 content types including audio, text, exercise, fact, video, etc. are used). In this study, we implemented the learner profile, course profile, matching strategies, and initialization and updating strategies.

MODA's agents were implemented as JADE (Java Agent Development Framework) agents, a middleware that facilitates the development of multi-agent systems. The agent behaviors are defined by learner's actions performed on the LMS, which are explained in the form of scenarios.

In order to have a standalone module for any LMS, we defined a common protocol establishing the communication between LMS and MODA. This protocol includes the structure of the data exchanges among LMS-MODA and the interface to support communication. MODA was integrated into an open source learning management system.

2. Adaptive Technologies and Adaptive Systems

Instructional approaches and techniques that are geared to meet the needs of individually different students are called adaptive instruction technologies [11]. Any type of instruction presented in a one-on-one setting can be considered as individualized instruction, but if it is not flexible enough to meet learner's specific learning needs, it cannot be considered as adaptive.

There are various adaptive technologies or strategies. In [2], these technologies are categorized as: ITS (Intelligent Tutoring Systems) technologies, adaptive hypermedia technologies, and web inspired technologies. InterBook [3] is a tool for delivering adaptive textbooks on the World Wide Web. It uses adaptive annotation technology. CALAT [4] is a web-based intelligent tutoring system (ITS). It employs overlay model and presents the courseware pages so that the student can achieve a learning goal consisting of hierarchical sub-goals. ACE (Adaptive Courseware Environment) [5] is a web-based tutoring framework, which combines methods of knowledge representation, instructional planning, and adaptive media generation to deliver individualized courseware via the web. ELM-ART II [6] is an intelligent interactive textbook to support learning programming in LISP. It supports adaptive navigation as individualized diagnosis and help in problem solving tasks. The system selects the next best step in the curriculum on demand.

There are some adaptive systems that consider cognitive and learning styles, such as iWeaver [12], INSPIRE [13], ARTHUR [14], CS388 [15], and AEC-ES [16]. IWeaver [12] is an interactive web-based adaptive learning environment. iWeaver uses the Dunn and Dunn learning style model. INSPIRE [13] is an adaptive intelligent system developed for personalized instruction in a remote environment. It adapts the lessons according to the learner's knowledge level and learning style, and follows his/her progress. ARTHUR [14] is a web-based system that provides adaptive instruction based on learning styles. It supports adaptive presentation using different teaching strategies. Student learning style is detected and tuned by means of case-based reasoning techniques. CS388 [15] offers a range of learning style tools to students. The learning styles are assessed using the Felder-

Silverman learning style model [17]. AEC-ES [16] categorizes learners as field-dependent and field-independent learners.

The adaptive systems explained above are either intelligent tutoring systems or adaptive hypermedia systems. However, they are not multi-agent. Multi-agent systems can improve the adaptability in online learning settings. As stated in [12], interaction is one (teacher) to many (students) in the traditional classroom environment. Online Learning Environments (OLE), on the other hand, supports one (server) to one (learner) communication. The learner's learning process is very dynamic and there are varieties of different factors affecting the learner's success. It might be effective to provide learners with instructional support assistants having separate responsibilities serving to the same purpose. In this study, we present a multi-agent system to support many (agents) to one (learner) interaction.

Pedagogical agents are autonomous agents that support human learning by interacting with students in the context of Intelligent Learning Environment (ILE). There are some personal agents such as COACH, an intelligent tutor; NOTE-TAKING APPRENTICE; MAXIMS an email-filter; GALOIS an intelligent adviser, etc. However, there are not many pedagogical agents developed so far [18]. ADELE (Agent for Distance Learning Environments)[8] is one of the pedagogical agents that runs on each student's computer and interacts with each student as they work through the Web-based course materials. PPP Persona [9] is an animated pedagogical agent for interactive WWW presentations.

In [19], the authors propose an intelligent agent to guide students throughout the course material in the Internet. They designed an adaptive hypermedia system that functions as a personal assistant to help teachers to generate course curriculum and to help students to navigate through the course material.

Much of the current research in intelligent agents has focused on individual agents. However, in order to be more effective, these agents must work cooperatively with each other as in Multi-Agent Systems (MAS).

3. MODA: A Module for Adaptiveness in LMSs

The aim of MODA is to integrate adaptive behaviour into online learning systems. The main components of the system are as follows:

- Student Modeling
- Adapted Content
- Integration with LMS

3.1 The Pedagogical Architecture

The effectiveness of the adaptation in online learning environments is highly related to the coverage of the adaptation strategy. The better the match between the learner and the instruction is, the higher the adaptation is. In this study, we applied a practical conceptual framework for adaptive systems [10]. The framework takes its background from learning styles and learning standards. The adaptation strategy in the framework is to find the best match between the learner and the instruction set.

The framework defines the learner profile and the course content profile, It also provides the way to find the best match between learner profile and course content profile. The learner profile has the following fields [10]:

- Personality factors: learning style information, IMS LIP (Instructional Management Systems Learner Information Package) fields
- Knowledge factors: identity of the content, identity of the content item (each course concept), type of the content item (one or more of 30 content types), the knowledge

level of the learner ("UNDERSTOOD","NOTUNDERSTOOD", "MISUNDERSTOOD"), exam results, and last modified date

- Behavioral factors: identity of the actions, identity of the learner, owner of the action (LMS or any other systems), name of the action (search, view lecture notes, login etc.), time to start action, time to end action, description of the action, counts for 30 content types

The course profile is defined by the following information [10]:

- Identification of the course
- Count of each of 30 content types

The 30 content types used in the framework are as follows:

- Activity
- Advance Organizer
- Audio
- Chart
- Concept
- Concept Map
- Critique
- Data
- Definition
- Diagram
- Discussion
- Example
- Exercise
- Experiment
- Fact
- Formula
- Image
- Innovation
- Link
- Mathematical model
- New concept
- Principle
- Problem solving
- Procedure
- Question
- Sequential content
- Suggestion
- Syllabus
- Textual
- Theory
- Table of contents
- Video

The framework provides a way to classify these content types according to the learning style dimensions. The study also defines a strategy to find the best match between the learner and course profiles. The formulation for finding the best match is as follows [10]:

The learner style values are defined by the vector $x=[x_1, x_2, .., x_8]$, and course content profile values are defined by the vector $y=[y_1, y_2, .., y_8]$, where x_i is the value of the i^{th} dimension of the learner style y_i is the value of the i^{th} dimension of the content profile. The two vectors x and y are normalized as follows:

$$x_{normalized} = [x_1/x_m, x_2/x_m, .., x_8/x_m]$$

$$y_{normalized} = [y_1/y_m, y_2/y_m, .., y_8/y_m]$$

where x_m is the maximum value in the x vector and y_m is the maximum value in the y vector.

The Euclidian distance between these two dimensions is computed as:

$$D(x,y) = \| x - y \| = ((x_{1normalized} - y_{normalized})^2 + ((x_{2normalized} - y_{2normalized})^2 + \ldots + (x_{8normalized} - y_{8normalized})^2)^{0.5}$$

So, the matching score is found as:

$$S(x, y) = - D(x, y)$$

The S (x, y) gives the matching score between the learner and course content profiles. This score is calculated for each item of the course content profile. The resulting scores are sorted and the course content with the highest score is accepted as the best matched course content regarding the learner profile.

In this study, we implemented the learner profile, course content profile, the classifications of the course content according to the learning styles, and the best matching strategy between the learner-content profiles.

3.2 The Multi-Agent System Architecture

MODA was designed to work with an LMS. We have three main modules: LMS, MODA and LMS-MODA interface module (Figure 1). LMS can be any LMS providing online learning services to learners. MODA is the multi-agent system module. LMS-MODA interface is the communication platform of these two separate modules. We developed a socket-based communication protocol.

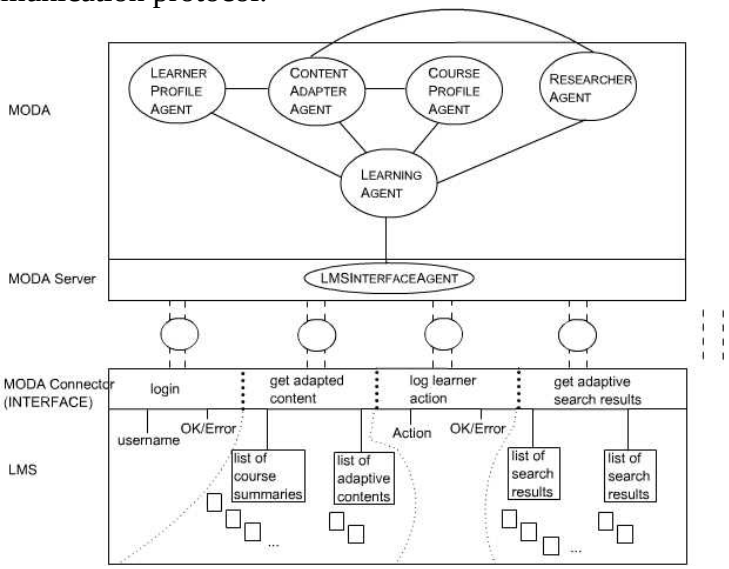

Figure 1 The Architecture of MODA

The system has six learning agents: LEARNINGAGENT, CONTENTADAPTER AGENT, COURSEPROFILEAGENT, LEARNERPROFILEAGENT, RESEARCHER AGENT and AGENTMANAGER. The descriptions and roles of each agent are as follows:

- LMSINTERFACEAGENT is the communication party with the LMS. It behaves as the MODA server.
- LEARNINGAGENT is the central agent, which is responsible for management of the other agents.
- CONTENTADAPTERAGENT is responsible for finding the most appropriate content for the learner using the learner profile. This agent communicates with the PROFILEAGENT, LEARNINGAGENT, and RESEARCHERAGENT.
- COURSEPROFILEAGENT initializes and updates the course profile.
- LEARNERPROFILEAGENT initializes and updates the learner profile.
- RESEARCHERAGENT receives search results, communicates with CONTENTADAPTERAGENT and receives the adapted content.

The agents in MODA were developed as JADE (Java Agent Development Framework) agents.

In the study, it is aimed that any LMS can make use of the adaptive learning module MODA. In order to achieve this modularity, we provide a protocol for communication between LMS and MODA. Any LMS providing necessary information with the required format becomes an adaptive learning management system, when it establishes a communication with MODA. The protocol requires LMS and MODA to read/write the necessary information to TCP sockets. Since the communication occurs in the sockets, we define the data formats exchanged between the systems during either requesting data or responding a request. In the MODA, one of the agents, - LMSINTERFACEAGENT-, serves as a server that receives the requests from the LMS and provides the responses back.

The request and response messages exchanged between LMS and MODA are depicted in Figure 2.

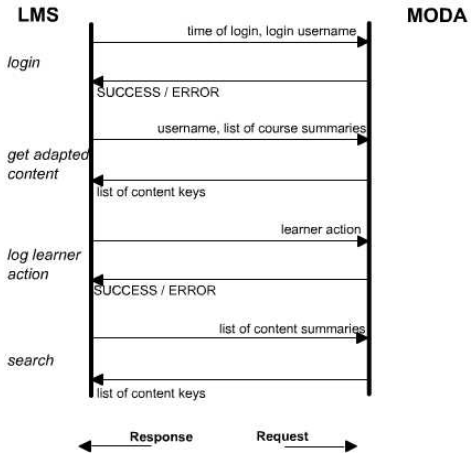

Figure 2 Request and Response Data in Communication Scenarios between LMS and MODA

Communication is performed through data packets. A packet can be either a request or a response packet. The packet structure of request and response are provided in the protocol [10].

4. An Example

MODA has been integrated to an open source learning management system, OLAT. More information on OLAT can be obtained at http://www.olat.org/website/en/html/index.html. Figure 4 shows the welcome page of OLAT integrated with MODA.

Figure 4 Welcome Page of OLAT with MODA

When the learner clicks “Show Content”, OLAT displays all available content resources to the learner. Figure 5 gives the sample screen for the OLAT showing the content after performing adaptation, filtering and sorting through MODA.

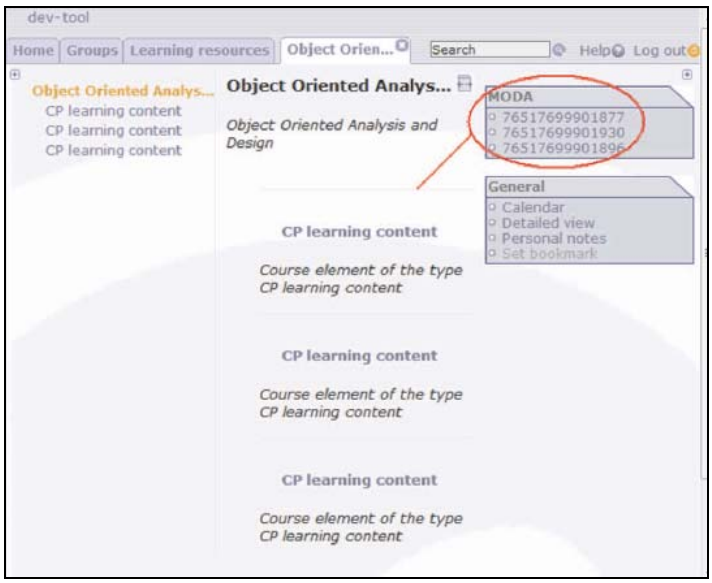

Figure 5 The adaptive content list

5. Conclusion

In this study, we designed and developed an adaptation module, called MODA, for learning management systems. A communication protocol was defined to establish the communication between LMS and MODA. Any LMS obeying the data requirements of the protocol can use MODA to be an adaptive learning system. MODA has been totally implemented using Java programming language. Since the protocol requires communicating through sockets, the development language of LMS becomes unimportant for the integration. This increases the usability of MODA in different LMS without considering the programming language limitations.

MODA is a multi-agent system. It has six agents each having specific roles such as registering agent's services, initializing and updating the learner profile, constructing course profile and performing course content classification, finding out the best match between the learner profile and course profile, and providing communication with LMS.

MODA provides curriculum sequencing and adaptive presentation technologies. It models the learner and the course content using a conceptual framework developed for adaptive systems [10]. It adapts the content according to the best match between the learner profile and the course profile.

The effectiveness of the adaptive strategies and technologies are directly correlated with the number and variety of the learners. This means that the development of MODA is a never-ending process. There will be new adaptive features to be added, or new best matching strategies will be applied as we use it more. It provides a platform to study different research topics.

References

[1] Park, I. & Hannafin, M.J. (1993). Empirically based guidelines for the design of interactive multimedia, *Educational technology Research and Development*, 41(3), Springer, pp.34-43.

[2] Brusilovsky, P. (1999). Adaptive and Intelligent Technologies for Web-basedEducation, *KI - Kunstliche Intelligenz*, Rollinger, Peylo (eds.), 4, pp.19-25.

[3] Brusilovsky, P., Eklund, J. & Schwarz, E. (1998). Web-based education for all: a tool for developing adaptive courseware, *Computer Networks and ISDN Systems,* 30(1), Elsevier, pp.291-300.

[4] Nakabayashi, K., Maruyama, M., Kato, Y., Touhei, H. & Fukuhara, Y. (1997). Architecture of an intelligent tutoring system on the WWW, *Proceedings of the 8th World Conference of the AIED Society*, Kobe, Japan, 18-22 August.

[5] Specht, M. & Oppermann, R. (1998). ACE - Adaptive Courseware Environment, *The New Review of Hypermedia and Multimedia,* 4, pp. 141-161.
[6] Weber, G. & Specht, M. (1997). User modeling and adaptive navigation support in WWW-based tutoring systems' *Proceedings of the 6 tn International Conference on User Modeling*, A. Jameson, C. Paris, and C. Tasso, Eds., Berlin Heidelberg: Springer-Verlag, pp. 289-300.
[7] López, J.M., Millán, E., Pérez-de-la-Cruz, J. L. & Triguero, F. (1998). ILESA: a Web-based Intelligent Learning Environment for the Simplex Algorithm, In: Alvegård, C. (ed.) , *Proceedings of 4th International conference on Computer Aided Learning and Instruction in Science and Engineering(CALISCE'98)*, Göteborg, Sweden, pp. 399-406.
[8] Johnson, W., Shaw, E., Marshall, A. & Labore, C. (2003). Evolution of user interaction: The case of agent adele, *Intelligent User Interfaces*, pp. 93-100.
[9] Andr´e, E., M¨uller,J. & Rist,T. (1996). The ppp persona: a multipurpose animated presentation agent, *In Proceedings of the workshop on Advanced visual interfaces(AVI'96)*, ACM, New York, NY, USA, pp. 245–247.
[10] Serce, F.C. (2007). An adaptive multi-agent system module for learning management systems, doctoral dissertation, Department of Information Systems, Middle East Technical University, Ankara, Turkey.
[11] Corno, L. & Snow, E. (1986). *Adapting Teaching to Individual Differences among Learners*, Handbook of Research on Teaching, New York: MacMillan Publishers.
[12] Wolf, C. (2003). iWeaver: towards 'learning style'-based e-learning in computer science education, *In Proceedings of the fifth Australasian conference on Computing Education(ACE'03)*, Darlinghurst, Australia, Australia, 2003, pp. 273–27.
[13] Grigoriadou, M., Papanikolaou, K., Kornilakis, H. & Magoulas G.(2002). Inspire: an intelligent system for personalized instruction in a remote environment, *Lecture Notes in Computer Science*, 2266, Springer, p. 215.
[14] Gilbert, C.Y. & Juan, E.H. (1999). Arthur: Adapting instruction to accommodate learning style, *In World Conference on the WWW and Internet Proceedings(WebNet 99)*, Honolulu, Hawaii, October 24-30, p. 7.
[15] Howard, R.A., Carver, C.A. & Lavelle, E. (1996). Enhancing student learning by incorporating learning styles into adaptive hypermedia, *In Proceedings of World Conference on Educational Multimedia and Hypermedia(ED-MEDIA 1996)*, Boston, USA, pp.118–123.
[16] Triantafillou, E., Pomportsis, A. & Georgiadou, E. (2002). Aes-cs: Adaptive educational system base on cognitive styles, *Proceedings of AH2002 Workshop, Second International Conference on Adaptive Hypermedia and Adaptive Web-based Systems*, University of Malaga, Spain.
[17] R. M. Felder and L. K. Silverman. *Learning and teaching styles in engineering education*. Engineering Education, 78(7):674–681, 1998.
[18] Marzo C. I. Pe˜na, J.L. & Rosa, J.L. (2005). Intelligent Agents to Improve Adaptivity in A0 Web-Based Learning Environment, *Chapter Studies in Fuzziness and Soft Computing, Knowledge-Based Virtual Education*, 178, Springer Berlin / Heidelberg, June, pp. 141–170.
[19] Ozdemir, B. & Alpaslan, F.N. (2000). An intelligent tutoring system for student guidance in web-based courses, *In Lecture Notes In Computer Science*, 1909, London, UK, Springer-Verlag, pp. 437–448.